Chapter 4
Research and Development: National Trends and International Linkages

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Highlights

Trends in National R&D Performance

U.S. R&D expenditures continued to rise in 2008, outpacing the overall expansion of the nation's economy.

- NSF estimates that overall spending on R&D conducted in the United States was $398 billion (current dollars) in 2008, up from $373 billion in 2007. This increase represents growth in 2008 of 6.7% over the 2007 level, or 4.5% in inflation-adjusted 2000 dollars. However, this 2008 figure may not fully reflect the effects of the downturn in U.S. and global economic conditions that intensified in late 2008.
- National R&D spending has increased mostly uninterrupted since 1953. Over the past 20 years, growth in R&D spending has averaged 5.6% in current dollars and 3.1% in constant dollars—somewhat ahead of the average pace of GDP growth over the same period (in both current and constant dollars).

The business sector accounts for most U.S. R&D performance and funding.

- The business sector performed an estimated $289 billion of R&D in 2008, or 73% of the U.S. total, drawing on both business and federal sources of R&D support. The business sector itself provided an estimated $268 billion of funding for R&D in 2008, or 67% of the U.S. total; almost all of it supported R&D performed by business. Over the past 5 years, expanded business spending has accounted for much of the nation's R&D growth.
- The academic sector is the second-largest performer of U.S. R&D, an estimated $51 billion in 2008, just under 13% of the U.S. total.
- The federal government is the second-largest funder of U.S. R&D, providing an estimated $104 billion, or 26% of the U.S. total in 2008.

U.S. R&D is dominated by development expenditures, largely performed by the business sector, and most basic research is conducted at universities and colleges.

- In 2008, basic research was about 17% ($69 billion) of the U.S. total, applied research was about 22% ($89 billion), and development was about 60% ($240 billion).
- Universities and colleges historically have been the main performers of U.S. basic research, an estimated 56% of total U.S. basic research in 2008. The federal government has been the prime source of basic research funding, accounting for 57% of the nation's total in 2008.
- The business sector, which currently accounts for more than half of all U.S. applied research funding, spends more than four times as much on applied research as on basic research.
- Development in the United States is chiefly a business sector activity, which performed 90% of the total development in 2008 and provided 84% of the funding. Most of the rest of development funding is provided by the federal government.

Location of R&D Performance

R&D is geographically concentrated, and states vary significantly in the types of research performed within their borders.

- In 2007, the 10 states with the greatest R&D expenditure levels accounted for 64% of all U.S. R&D expenditures. California alone represented 22% of U.S. R&D—triple that of Massachusetts, the next highest state. New Mexico, Massachusetts, and Maryland had the highest R&D-to-GDP ratios in 2006. California ranked seventh in R&D/GDP intensity.
- Massachusetts, Illinois, California, and Texas accounted for about two-thirds of the R&D performed by computer and electronics products companies in 2007; New Jersey, Connecticut, and Pennsylvania are the leaders in chemicals manufacturing, accounting for 41% of the R&D in that industry.
- Nationally, small companies (defined as having from 5 to 499 employees) perform 19% of the nation's total business R&D. The R&D performance of these small companies is concentrated geographically. Among the top 10 business R&D-performing states, New York and California had the highest totals of small companies performing business R&D, with 23% and 20%, respectively.

Business R&D

Business sector R&D rose to its highest level in 2007. Although 2008 projections show additional growth, they do not reflect the effects of the U.S. economic downturn.

- R&D performed by the business sector is estimated to have reached $269 billion in 2007 and is projected to have increased to $289 billion in 2008.
- The company-funded R&D-to-sales ratio of companies in all industries performing R&D in the United States varied between 3.2% and 3.4% during 2003–06; in 2007 it was 3.5%.
- Over three-fourths of business R&D is performed in six business sectors. The R&D-to-sales ratio for these sectors as a group was 8.0% in 2007, compared with 1.4% for all other business sectors.

Federal R&D

Federal R&D spending continued to grow in recently proposed and enacted budgets and received further increases through the American Recovery and Reinvestment Act.

- ♦ Budget appropriations for federal spending on R&D in FY 2009 totaled $147.1 billion (current dollars), an increase of $3.3 billion (or 2.4%) over the enacted FY 2008 spending level. The proposed overall increase for FY 2010 is smaller (0.4%).
- ♦ However, the American Recovery and Reinvestment Act (ARRA) of 2009 included a one-time additional increase in R&D funding that is estimated to total $18.3 billion in FY 2009.
- ♦ In the FY 2009 budget, increases in R&D funding were greatest for the National Institutes of Health (NIH), the Department of Energy (DOE), and the National Science Foundation (NSF). Along with the National Aeronautics and Space Administration and the National Institute of Standards and Technology, these agencies also received the largest increases from ARRA.
- ♦ Defense continues to be the largest function in the federal R&D budget. It accounted for 59% of the federal total (budget authority) in FY 2008.
- ♦ The most dramatic change in national R&D priorities over the past 25 years has been the large rise in health-related R&D, which grew from 25% of the federal nondefense R&D budget in FY 1980 to 55% in FY 2005. In FY 2008, health accounted for 52% of the nondefense R&D budget.

Federal R&D Tax Credit

- ♦ Along with direct funding of R&D, the government also promotes the conduct of R&D through tax incentives. About 11,000 U.S. companies claimed an estimated $7.3 billion in federal research and experimentation tax credits in 2006, compared with $6.4 billion in 2005.

International R&D Comparisons

Many countries conduct R&D, but much of global R&D performance continues to be concentrated in a few high-income countries and regions.

- ♦ Worldwide R&D expenditures totaled an estimated $1.107 trillion in 2007 (the latest year for which data are available). The United States accounted for about 33% of this total. Japan, the second-largest performer, accounted for about 13%. China was third, at about 9%. Germany and France, respectively, fourth and fifth (and the largest performers in Europe), accounted for 6% and 4%, respectively. The top 10 countries (also including South Korea, the United Kingdom (UK), the Russian Federation, Canada, and Italy) account for almost 80% of current global R&D performance.
- ♦ The 27 nations of the European Union (EU-27) accounted for about 24% of global R&D. R&D by the EU-27 grew at an average annual constant dollar rate of 3.3% between 1997 and 2007. By comparison, the U.S. pace of growth, on the same basis, averaged 3.3%.
- ♦ Recent growth in R&D expenditures has been most dramatic in China, averaging just above 19% annually in inflation-adjusted dollars over the past decade.

Wealthy economies generally devote larger shares of their gross domestic product (GDP) to R&D than do less developed economies.

- ♦ The U.S. R&D/GDP ratio was 2.7% in 2007 and has fluctuated between 2.6% and 2.8% over the past 10 years, largely reflecting changes in business R&D spending. In 2007, the United States ranked eighth among the economies tracked by the OECD; Japan, South Korea, and several smaller developed economies had higher ratios.
- ♦ Among the major European R&D-performing countries, Italy (2006) and the Russian Federation (2007) had R&D/GDP ratios of 1.1%. The UK ratio was 1.8% in 2007, and those of France and Germany were 2.1% and 2.5%, respectively, in 2007. Canada's R&D/GDP ratio was 1.9% in 2007. Over the past 10 years, these ratios were stable or changed only modestly.
- ♦ R&D/GDP ratios increased substantially in Japan, South Korea, and China over the past 10 years. The Japanese and South Korean ratios were among the highest in the world in 2007, at 3.4% and 3.5% respectively. China's ratio remains relatively low, at 1.5%, but has more than doubled from 0.6% in 1996.

Among the countries with the largest R&D expenditures, the business sector accounts for the bulk of total R&D performance.

- ♦ Among the top 10 countries for R&D expenditures, the business sector is the largest R&D performer, ranging from 77% for South Korea and Japan to 49% for Italy.
- ♦ No single industry accounted for more than 18% of total business R&D in the United States in 2007; many other countries displayed much higher industry and sector concentrations.
- ♦ The pharmaceuticals industry accounts for more than 25% of business R&D in Denmark and the United Kingdom, and more than 20% in Belgium and Ireland. The computers, office and accounting machines industry represents only a small share of business R&D in most countries; only Japan reports a double-digit concentration of business R&D in this industry. The service sector accounted for 30% or more of all business R&D in many countries of the Organisation for Economic Co-operation and Development (OECD), including the United States.

R&D by Multinational Companies

Multinational companies (MNCs) represent a substantial component of U.S. R&D. Overseas R&D by U.S. MNCs reflects gradual changes in their geographic focus.

- Majority-owned affiliates of foreign-based MNCs spent $34.3 billion on U.S. R&D in 2006, up from $31.1 billion in 2005. Their U.S. R&D expenditures have grown faster than total U.S. business R&D and have represented about 14% of U.S. business R&D since 2003, up from the single digits in the early 1990s.
- U.S. MNCs performed $216.3 billion in R&D worldwide in 2006, including $187.8 billion in the United States by parent companies and $28.5 billion by their overseas affiliates. The R&D by MNC parents represented 87% of their global R&D and about 76% of total U.S. business R&D. Both shares have changed little in recent years. However, the geographic distribution of R&D by their overseas affiliates is gradually reflecting the role of emerging markets.
- Europe, Canada, and Japan accounted for a decreasing share of R&D by overseas affiliates of U.S. MNCs, representing 90% in 1994 and 80% in 2006. Over the same period, the share performed in Asia (excluding Japan) rose from 5.4 % to 13.5%, driven by affiliates' R&D spending in China, Singapore, and South Korea.
- R&D performed by U.S.-owned affiliates located in China and India increased from less than $10 million in each country in 1994 to $804 million and $310 million, respectively, in 2006. Although the 2006 levels for China and India represented only about 3% and 1%, respectively, of total overseas R&D by U.S. MNCs, funding levels in some lower cost locations may still be significant from the perspective of purchasing power.

Technology and Innovation Linkages

Federal agencies and laboratories continue to engage in collaborative and technology transfer activities. Business increased its R&D funding to contractors within the United States.

- Federal agencies participated in more than 7,000 formal Cooperative Research and Development Agreements in 2007 and more than 9,000 less formally structured collaborative R&D relationships. Federal agencies issued more than 1,400 patents in 2007 and held more than 10,000 active licenses based on their total stock of intellectual property.
- Businesses in the United States reported contracting out an estimated $19.0 billion in R&D to other U.S.-located companies in 2007, compared with $12.4 billion in 2006. This increased the ratio of contracted-out R&D to company-funded and company-performed R&D from 5.5% in 2006 to 7.8% in 2007. For manufacturers, the ratio reached 8.5% in 2007, up from 5.7% in 2006.

International trade in R&D services and technology alliances indicate the role of external sources and cooperative arrangements aimed at acquiring or jointly developing new knowledge.

- In 2007, the United States maintained a trade surplus in research, development, and testing services of $3.3 billion. Trade within MNCs dominates these statistics—which is not surprising, given their large role in U.S. R&D performance.
- Almost 900 worldwide business technology alliances were established in 2006, approximately two-thirds of which involved at least one U.S.-owned company regardless of location. Since 1999, the proportion of U.S.-foreign alliances has surpassed U.S.-only alliances, a change driven by rapid growth in alliances with European companies. However, in 2006 the number of U.S. alliances with Asian non-Japanese partners (50) reached parity with U.S.-Japan alliances (54), reflecting growth of the former since 1990.

Introduction

As we come to the end of the first decade of the 21st century, global economic trends are leading governments of most nations to implement financial market support measures and economic recovery packages. These policies often include measures to stimulate productivity, growth, and innovation through support of R&D—widely viewed as a long-term contributor to economic growth and national competitiveness.

The importance accorded to investment in R&D and innovation in public policy discussions is reflected in the national and international initiatives that help us better understand and measure their results. The America COMPETES Act (Public Law 110-69) and the American Recovery and Reinvestment Act of 2009 (Public Law 111-5) both address the importance of the U.S. innovation system for national economic growth.

Federal statistical agencies seek to incorporate R&D in the system of national accounts to measure, for example, its relation to gross domestic product (GDP) and productivity growth. These agencies are also exploring the role of cross-border investment in R&D and other intangibles. The National Science Foundation (NSF) is conducting a new Business R&D and Innovation Survey to collect a broad range of indicators that will form a platform for future modules on innovation. (See sidebar "New U.S. Business R&D and Innovation Survey.")

An ongoing project conducted by the Organisation for Economic Co-operation and Development (OECD) to design an Innovation Strategy examines how changes in the innovation enterprise of OECD member nations may affect their ability to achieve certain government and socioeconomic goals. Concurrently, the OECD, United Nations Statistical Commission, and other international bodies are collaborating to update or develop statistical manuals on intangibles,

New U.S. Business R&D and Innovation Survey

To better understand how R&D is conducted in today's innovation- and global-based economy and to investigate ways to improve NSF's portfolio of R&D measurements, NSF commissioned a study by the National Research Council's Committee on National Statistics (CNSTAT) in 2004. The committee published its findings in the 2005 report *Measuring Research and Development Expenditures in the U.S. Economy* (NRC 2005a). The essence of CNSTAT's concerns and recommendations centered on the finding that a new, more comprehensive survey was needed to "keep up with the fast-changing environment for the conduct and organization of research in the private business sector" (NRC 2005a, p 4).

In early 2009, NSF and the U.S. Census Bureau launched a new Business R&D and Innovation Survey (BRDIS). The survey covers manufacturing and service companies and includes questions on a broad range of R&D topics (listed below). The survey also begins to collect innovation data, with the ultimate objective of increasing the number and breadth of innovation-related items in the future.

- ♦ Financial measures of R&D activity:
  - Domestic and worldwide sales and revenue
  - Detail on domestic and worldwide R&D activity
  - Company R&D expense by business segment, type of expense, and location (state and country)
  - Capital expenditures for R&D (buildings, software, equipment)
  - Projected R&D expense
- ♦ Measures of company R&D activity funded by others:
  - Funds for worldwide and domestic R&D activity
  - R&D funded by others—by business segment, type of organization, type of expense, state, and location (domestic vs. foreign)
- ♦ Measures of R&D employment:
  - R&D headcount (domestic and worldwide) by occupation and sex
  - Number of U.S. R&D employees working under a visa (H-1B, L-1, and so on)
  - R&D full-time equivalent counts
- ♦ Measures related to R&D management and strategy:
  - R&D partnerships
  - Share of R&D for the social sciences, new business areas, and specific applications
- ♦ Measures of intellectual property (IP), technology transfer, and innovation:
  - Participation in activities to introduce new or significantly improve existing goods, services, methods of production and distribution, or support systems
  - Patent-related data-number owned or applied for
  - Participation in specific technology transfer activities
  - Importance of types of IP protection
  - Licensing to outside parties

For more information on the new survey, see NSF/SRS (2008b).

national economic accounts, and trade in services. The purpose of these efforts is to better harmonize data that will serve as future indicators for measuring innovation.

Chapter Organization

This chapter is organized into seven main sections. An overview of national trends in the performance and funding of R&D is followed by a discussion of state-level R&D patterns and trends. A third section covers business, the largest performer and funder of U.S. R&D. This section is followed by a discussion of the patterns of federal government R&D, including how those patterns play out in the defense, energy, and health arenas, and concludes with federal tax incentives for business R&D.

The last three sections of the chapter cover international comparisons of R&D, investments by multinational companies (MNCs), and technology and innovation linkages, respectively. International comparisons of R&D include national R&D expenditures by performer and source, national R&D intensities, and government R&D priorities. The section devoted to MNCs covers overseas investments of U.S. MNCs and U.S. R&D by foreign-owned companies. Although global R&D is concentrated in a few developed countries or regions, China and other emerging Asian countries have increased their R&D expenditures and have become hosts to R&D conducted by U.S. MNCs. The last section covers business-to-business external sourcing, technology alliances, and international transactions in R&D services. The latter represents the convergence of service-oriented R&D and global innovation networking. This section concludes with a discussion of innovation-related federal programs and activities aimed at technology transfer, R&D, and new technology development and deployment by small firms.

Trends in National R&D Performance

R&D, along with other social, economic, and technological factors, creates new knowledge and contributes to innovation and the introduction of new goods, services, processes, and managerial practices. Suppliers and users of R&D include businesses, educational institutions, not-for-profit research organizations, and governments. Statistics on R&D expenditures reported by performing and funding organizations are used as metrics throughout the United States and internationally.[1] (See sidebar “Definitions of R&D.”)

NSF estimates indicate that overall spending on R&D conducted in the United States was $397.6 billion (current dollars) in 2008, up from $372.5 billion in 2007 (table 4-1). This represents growth of 6.7%, or 4.5% in inflation-adjusted

Definitions of R&D

R&D. According to international guidelines for conducting R&D surveys, R&D, also called research and experimental development, comprises creative work “undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and the use of this stock of knowledge to devise new applications” (OECD 2002).

Basic research. The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed to fields of current or potential interest. This focus is often the case when performed by industry or mission-driven federal agencies.

Applied research. The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Development. Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

R&D plant. This term refers to the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Budget authority. Budget authority is the authority provided by federal law to incur financial obligations that will result in outlays. The basic forms of budget authority are appropriations, contract authority, and borrowing authority.

Obligations. Federal obligations represent the dollar amounts for orders placed, contracts and grants awarded, services received, and similar transactions during a given period, regardless of when funds were appropriated or payment was required.

Outlays. Federal outlays represent the dollar amounts for checks issued and cash payments made during a given period, regardless of when funds were appropriated or obligated.

For an annotated compilation of definitions of R&D by U.S. statistical agencies, tax statutes, accounting bodies, and other official sources, see NSF/SRS (2006).

(also called constant or real) 2000 dollars.[2] The 2008 figures are preliminary, however, and may not yet fully reflect the effects of the sharp downturn in the U.S. economy and globally beginning in late 2008.

Total estimated R&D expenditures in 2008 were $13.9 billion higher in real dollars than in 2007 (table 4-1). Most of this increase reflected estimated increases in business R&D expenditures and funding.

Over the longer term, increases in national R&D spending have been largely uninterrupted since 1953 in both current and real dollars (figure 4-1). The rates of the past several years have been above the average annual growth rate over the past 20 years (5.6% in current dollars, 3.1% in constant dollars). U.S. R&D spending crossed the $100 billion (current dollars) threshold in 1984, passed $200 billion in 1997, was nearly $300 billion in 2004, and almost reached

Table 4-1
U.S. R&D expenditures, by performing sector and funding source: 2003–08

Sector	2003	2004	2005	2006	2007	2008
	Current $millions					
All performing sectors	288,324	299,201	322,104	347,046	372,527	397,616
Business	200,724	208,301	226,159	247,669	269,267	289,105
Federal government	35,005	35,632	37,716	38,926	39,897	41,741
Federal intramural[a]	22,752	22,844	24,470	25,556	25,858	27,000
FFRDCs	12,253	12,788	13,246	13,369	14,039	14,741
Industry-administered[b]	2,458	2,485	2,601	3,122	4,839	5,031
U&C-administered[b]	7,301	7,659	7,817	7,306	5,892	6,023
Nonprofit-administered	2,494	2,644	2,828	2,941	3,308	3,688
Universities and colleges	40,484	43,128	45,197	46,983	49,021	51,163
Other nonprofit	12,111	12,140	13,032	13,469	14,341	15,606
All funding sources	288,324	299,201	322,104	347,046	372,527	397,616
Business	186,174	191,376	207,826	227,254	246,927	267,847
Federal government	83,618	88,766	93,817	98,036	101,764	103,696
Universities and colleges	7,650	7,937	8,579	9,307	9,993	10,600
Nonfederal government	2,742	2,883	2,922	3,021	3,249	3,453
Other nonprofit	8,140	8,239	8,960	9,429	10,593	12,020
	Constant 2000 $millions					
All performing sectors	270,971	273,335	284,962	297,444	310,913	324,791
Business	188,643	190,294	200,081	212,271	224,732	236,155
Federal government	32,898	32,551	33,367	33,362	33,299	34,096
Federal intramural[a]	21,383	20,869	21,648	21,904	21,582	22,055
FFRDCs	11,516	11,682	11,719	11,459	11,717	12,042
Industry-administered[b]	2,310	2,270	2,301	2,676	4,039	4,109
U&C-administered[b]	6,861	6,997	6,916	6,262	4,918	4,920
Nonprofit-administered	2,344	2,415	2,502	2,521	2,761	3,012
Universities and colleges	38,047	39,400	39,986	40,268	40,913	41,792
Other nonprofit	11,382	11,090	11,529	11,544	11,969	12,748
All funding sources	270,971	273,335	284,962	297,444	310,913	324,791
Business	174,969	174,831	183,862	194,773	206,087	218,790
Federal government	78,585	81,092	82,999	84,024	84,933	84,704
Universities and colleges	7,190	7,251	7,589	7,977	8,341	8,658
Nonfederal government	2,577	2,634	2,585	2,589	2,711	2,821
Other nonprofit	7,650	7,527	7,926	8,081	8,841	9,818

FFRDC = federally funded research and development center; U&C = universities and colleges

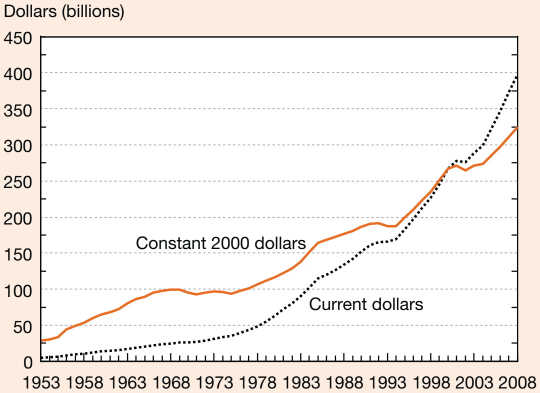
[a]Includes expenditures of federal intramural R&D and costs associated with administering extramural R&D.
[b]In June 2006, Los Alamos National Laboratory (approximately $2 billion in annual R&D expenditures in recent years) became industry administered; previously, U&C administered. This shift is one reason for change in trends apparent in R&D expenditure figures between 2006 and 2007.

NOTES: Data for 2008 are preliminary. Data based on annual reports by performers except for nonprofit sector. Expenditure levels for academic and federal government performers are calendar-year approximations based on fiscal year data. For federal government expenditures, approximation equal to 75% of amount reported in same fiscal year plus 25% of amount reported in subsequent fiscal year. For academic expenditures, respective percentages are 50 and 50, because those fiscal years generally begin on 1 July instead of 1 October.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 and 4-7.

Science and Engineering Indicators 2010

Figure 4-1
U.S. total R&D expenditures: 1953–2008



NOTE: Data for 2008 are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-3.

Science and Engineering Indicators 2010

$400 billion in 2008. Over the past 20 years, the expansion of U.S. R&D spending has exceeded the pace of GDP growth, which averaged 5.3% in current dollars and 2.8% in constant dollars, with the difference becoming more substantial in the past few years.

The economic stimulus package enacted in early 2009 (American Recovery and Reinvestment Act of 2009 [Public Law 111-5]) provided a substantial increase in federal FY 2009 funding for R&D and R&D infrastructure ($18.3 billion). However, these one-time funds do not enter into the federal funding base for subsequent fiscal year budgets, as discussed in the federal R&D section of this chapter.

Estimates of U.S. R&D expenditures are generated by adding the annual R&D spending of all sectors of the economy for which expenditures can be reasonably estimated. The spending figures come from surveys of organizations that historically have performed the vast majority of R&D in the United States; however, some components of national R&D performance are not reflected in current NSF data, and measurement challenges remain. For a further discussion of R&D activities not currently captured in NSF's official R&D statistics, see the sidebar "Unmeasured R&D."

Unmeasured R&D

The estimates of U.S. R&D presented in this volume are derived from surveys of organizations that have historically performed the vast majority of R&D in the United States. To evaluate U.S. R&D performance over time and in comparison with other countries, however, it is necessary to gauge how much R&D goes unmeasured. The following paragraphs describe types of unmeasured R&D performance in the United States.

To reduce cost and respondent burden, U.S. industrial R&D estimates are derived from a survey of R&D-performing companies with five or more employees. Accordingly, no estimates of R&D performance are available for companies with fewer than five employees.

The activity of individuals performing R&D on their own time and not under the auspices of a corporation, university, or other organization is similarly omitted from official U.S. R&D statistics.

Social science R&D has been excluded from U.S. industrial R&D statistics. Also, R&D in the humanities is excluded from U.S. academic R&D statistics. Other countries include both in their national statistics, making their national R&D expenditures relatively larger when compared with those of the United States. (The new U.S. Business R&D and Innovation Survey, being fielded for the first time in 2009, includes social science R&D and will better capture total federally funded R&D performed by others. Furthermore, NSF is in the process of redesigning its Higher Education R&D Survey, which will include non-S&E R&D expenditures in its reported totals.)

NSF has not conducted a survey on R&D performance by nonprofit organizations since 1998, although the R&D performance of nonprofits is estimated for national R&D totals. NSF and the U.S. Census Bureau collected statistics for R&D performance by state governments in the United States for 2006 and 2007, but these data have not yet been included in the national time series. Data for these performers are discussed in "Location of R&D Performance."

Performers of R&D

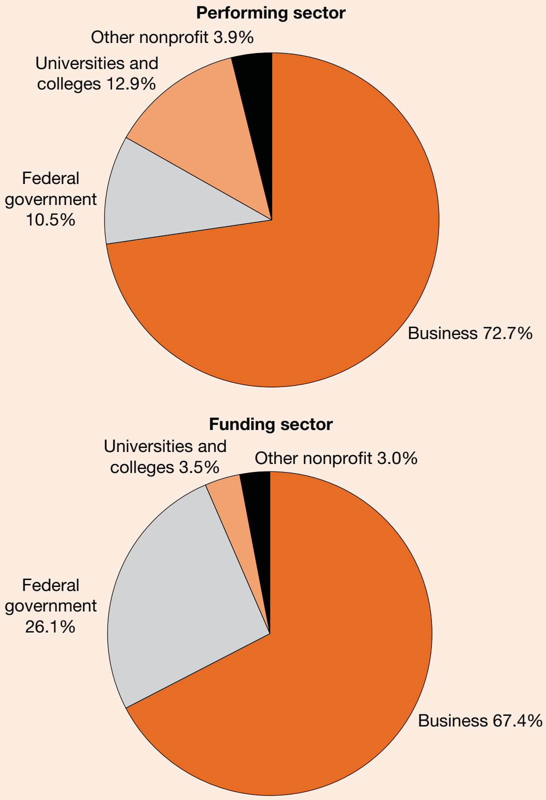
NSF tracks the R&D spending patterns of several performers in the overall U.S. R&D system: businesses, the intramural R&D activities of federal agencies, federally funded R&D centers (FFRDCs),[3] universities and colleges, and other nonprofit organizations.

Business Sector

Estimated spending for R&D performed in the United States by businesses totaled $289.1 billion (current dollars) in 2008 (table 4-1). NSF estimates that business R&D expenditures in 2008 expanded in real terms (constant dollars) by 5.1%, outpacing the real growth of total U.S. R&D in the same year (4.5%). Similarly high rates of growth prevailed for business R&D in 2005, 2006, and 2007, and again, the growth in business R&D outpaced that of total U.S. R&D.

The business sector is by far the largest performer of U.S. R&D, accounting for 73% of the total in 2008 (figure 4-2). The high-water mark of the business sector's share of U.S. R&D to date was 75% in 2000. Over the next 4 years, its

Figure 4-2
Shares of national R&D expenditures, by performing and funding sectors: 2008

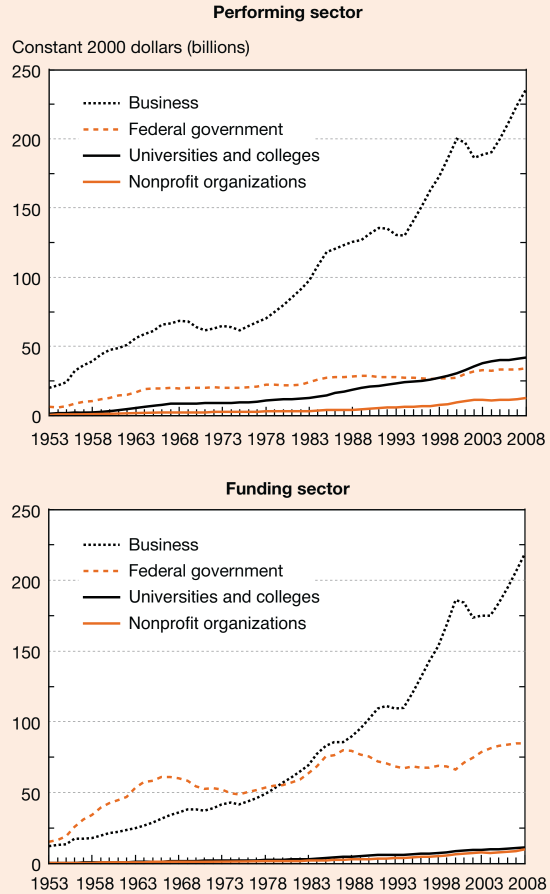


NOTES: Data for 2008 are preliminary. National R&D expenditures are estimated to be $398 billion in 2008. Federal performing sector includes federal agencies and federally funded research and development centers. State and local government support to industry is included in industry support for industry performance. State and local government support to universities and colleges is included in universities and colleges support of universities and college performance. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 and 4-7.

Science and Engineering Indicators 2010

Figure 4-3
National R&D, by performing and funding sectors, 1953–2008



NOTES: Data for 2008 are preliminary. Federal performers of R&D includes federal agencies and federally funded research and development centers. State and local government support to industry is included in industry support for industry performance. State and local government support to universities and colleges is included in universities and colleges support of universities and college performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 and 4-7.

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share declined to about 70% in response to the slowdown of the U.S. economy in 2001 and 2002 and the associated curtailment of business activities by many R&D-performing firms. With the renewal of vigorous business activity thereafter, business spending on R&D moved to a higher-growth path. The business sector's share of R&D rose above 70% in 2005 and has since continued to increase.

Over the past 5 years, expanded business spending on R&D has accounted for much of the growth (in both current and real-dollar terms) in all U.S. R&D spending. The most striking trend when contrasting business-sector R&D with that of other performers over the past several decades is the sustained, far larger real-dollar expansion in the level of R&D spending by the business sector (figure 4-3).

As discussed in the section "R&D by Character of Work," three-quarters of the business sector's R&D performance in recent years has been directed toward development activities rather than basic and applied research. Other U.S. R&D performers are relatively more active with respect to basic and applied research.

The business sector is the chief source of funding for its own R&D spending. In 2008, it is estimated that $263.3 billion, or 91%, of the business sector's overall R&D expenditures ($289.1 billion) came from the business sector itself (table 4-2), with the balance ($25.8 billion) coming from the federal government. Before the late 1960s, the

Table 4-2
U.S. R&D expenditures, by character of work, performing sector, and funding source: 2008

Sector	Total	Business	Federal government	Universities and colleges	Other nonprofit	Total expenditures (% distribution)
R&D	397,616	267,847	103,696	14,053	12,020	100.0
Business	289,105	263,310	25,795	*	*	72.7
Federal government	41,741	*	41,741	*	*	10.5
Federal intramural	27,000	*	27,000	*	*	6.8
FFRDCs	14,741	*	14,741	*	*	3.7
Industry-administered	5,031	*	5,031	*	*	1.3
U&C-administered	6,023	*	6,023	*	*	1.5
Nonprofit-administered	3,688	*	3,688	*	*	0.9
Universities and colleges	51,163	2,908	30,177	14,053	4,024	12.9
Other nonprofit organizations	15,606	1,629	5,982	*	7,995	3.9
Percent distribution by source	100.0	67.4	26.1	3.5	3.0	na
Basic research	69,146	12,222	39,379	10,188	7,357	100.0
Business	11,907	9,209	2,697	*	*	17.2
Federal government	10,189	*	10,189	*	*	14.7
Federal intramural	4,734	*	4,734	*	*	6.8
FFRDCs	5,455	*	5,455	*	*	7.9
Industry-administered	2,287	*	2,287	*	*	3.3
U&C-administered	1,736	*	1,736	*	*	2.5
Nonprofit-administered	1,432	*	1,432	*	*	2.1
Universities and colleges	38,822	2,108	23,608	10,188	2,918	56.1
Other nonprofit organizations	8,229	904	2,885	*	4,439	11.9
Percent distribution by source	100.0	17.7	57.0	14.7	10.6	na
Applied research	88,578	53,827	28,649	3,169	2,934	100.0
Business	61,437	52,758	8,679	*	*	69.4
Federal government	11,599	*	11,599	*	*	13.1
Federal intramural	7,573	*	7,573	*	*	8.5
FFRDCs	4,026	*	4,026	*	*	4.5
Industry-administered	1,067	*	1,067	*	*	1.2
U&C-administered	1,644	*	1,644	*	*	1.9
Nonprofit-administered	1,315	*	1,315	*	*	1.5
Universities and colleges	10,556	656	5,824	3,169	908	11.9
Other nonprofit organizations	4,985	413	2,546	*	2,026	5.6
Percent distribution by source	100.0	60.8	32.3	3.6	3.3	na
Development	239,891	201,798	35,669	696	1,729	100.0
Business	215,761	201,342	14,419	*	*	89.9
Federal government	19,953	*	19,953	*	*	8.3
Federal intramural	14,693	*	14,693	*	*	6.1
FFRDCs	5,260	*	5,260	*	*	2.2
Industry-administered	1,676	*	1,676	*	*	0.7
U&C-administered	2,643	*	2,643	*	*	1.1
Nonprofit-administered	941	*	941	*	*	0.4
Universities and colleges	1,785	144	746	696	199	0.7
Other nonprofit organizations	2,392	312	551	*	1,530	1.0
Percent distribution by source	100.0	84.1	14.9	0.3	0.7	na

* = small to negligible amount, included as part of funding provided by other sectors; na = not applicable

FFRDC = federally funded research and development center; U&C = universities and colleges

NOTES: Data for 2008 are preliminary. Federal intramural includes federal intramural R&D and costs associated with administering extramural R&D. Funding for FFRDC performance chiefly federal, but any nonfederal support included in federal figures. State and local government support to industry included in industry support for industry performance. State and local government support to universities and colleges ($3,453 million) included in universities and colleges support for universities and colleges performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 to 4-10.

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federal government was the primary source of funding for business R&D.

Note that the decline in federal funding of business R&D, as reported by businesses, differs somewhat from the trend apparent in R&D spending data collected from federal agencies. For details on this discrepancy, see the sidebar "Tracking R&D: The Gap Between Performer- and Source-Reported Expenditures" later in this chapter.

Universities and Colleges

Universities and colleges performed an estimated $51.2 billion of R&D in 2008. The academic sector is the second-largest performer of U.S. R&D. It currently represents just below 13% of total U.S. R&D performance, about a fifth of the size of business R&D. In the late 1990s and first years of the current decade, academic R&D grew faster than R&D in any other U.S. sector, with real annual growth rates in the range of 6% to 8%. After 2004, however, real growth has been much slower, falling to 2.1% in 2008, well below the real growth rates for business R&D and total U.S. R&D.

Universities and colleges are estimated to have performed more than half (56%) of the nation's basic research in 2008. (See "R&D by Character of Work.") They also rely much more than the business sector on external R&D funding. In 2008, about 27% of academic R&D was funded by the institutions themselves; 59% was funded by the federal government; and the balance was funded by state and local governments, nonprofits and other types of organizations, and private gifts (table 4-2).

Federal Agencies and FFRDCs

R&D performance by the federal government (which spans the activities of agency intramural research laboratories, agency planning and administration of both intramural and extramural R&D projects, and the FFRDCs) totaled an estimated $41.7 billion in 2008, about 11% of all U.S. R&D performance. Federal agencies' intramural R&D activities (including the aforementioned planning and administration costs) accounted for $27.0 billion (6.8%) of the U.S. total, and FFRDCs accounted for $14.7 billion (3.7%). Federal agencies' intramural R&D performance is entirely funded by the federal government; FFRDCs also rely chiefly on federal funding, with small amounts of nonfederal funds at some facilities.

Real expenditures for R&D conducted by federal agencies and FFRDCs combined grew rapidly from 2001 to 2003, reflecting increased defense spending following the terrorist attacks of September 11, 2001. From 2004 to 2007, federal government R&D performance was essentially flat. It is estimated to have returned to modest growth in 2008, with increases in both federal intramural and FFRDC R&D performance.

The volume of the federal government's R&D performance is small compared with that of the U.S. business sector. However, the federal sum of $41.7 billion exceeds the national R&D expenditures of every country except Japan, China, and Germany. Furthermore, this federal expenditure does not include sizable government investments in R&D infrastructure and equipment. In addition, the federal government maintains research facilities and conducts research projects that would be too costly or risky for a single company or university to undertake.

Other Nonprofit Organizations

The figure for R&D performed in the United States by other nonprofit organizations in 2008 was an estimated $15.6 billion. This amount represents about 4% of all U.S. R&D in that year, a share that has been fairly stable since 2000.

Sources of R&D Funding

The funding for R&D conducted by organizations in the United States comes from a variety of sources, including their own funds, as well as contracts and grants from other organizations. The funding mix varies across the main performing sectors. Data on the flows of R&D funding within sectors, such as between two companies, are limited, but data on the flows of R&D between sectors indicate that financial relationships between organizations play a significant role in the U.S. R&D system.

In 2008, an estimated 19% of U.S. R&D ($74 billion, current dollars) came from funding by an organization in a sector other than the performing sector (table 4-2). Most of this between-sector funding comes from the federal government, which supports significantly more R&D than it conducts in its own laboratories and FFRDCs. In sharp contrast, most businesses use a high percentage of their R&D budgets for internal projects or to contract for R&D performed by other businesses. The small remainder—about 2% of overall business funds for R&D—flows to universities and other nonprofit organizations to support R&D performance.

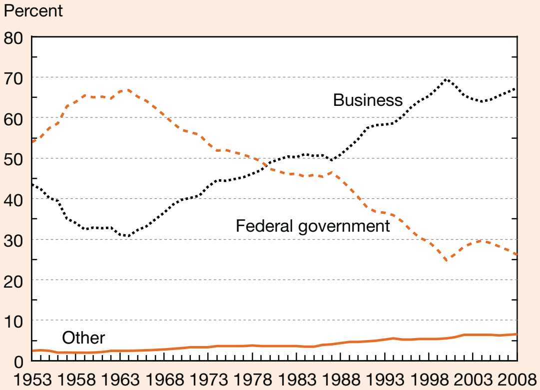
R&D Funding by the Federal Government

In 2008, according to the reports of R&D performers, the federal government funded an estimated $103.7 billion (current dollars) of R&D (table 4-1). This amount represented about 26% of all R&D funding in the United States (figure 4-2).

The federal government was once the predominant sponsor of the nation's R&D, funding some 67% of all U.S. R&D in 1964 (figure 4-4). But the federal share decreased in subsequent years, falling to below 50% in 1979 and to a low of 25% in 2000. This declining share of federal R&D funding is particularly evident in the business sector. In the late 1950s and early 1960s, more than half of the nation's business R&D was funded by the federal government, but by 2000, less than 10% of business R&D was federally funded (appendix table 4-3).

Between 2001 and 2004, however, this decades-long trend was attenuated as private investment slowed in the face of the 2001–02 recession. In addition, federal R&D spending expanded, first in health and then in defense and counterterrorism. By 2004, the federal share of the nation's

Figure 4-4
National R&D expenditures, by funding source: 1953–2008



NOTES: Data for 2008 are preliminary. Other includes universities and colleges, state and local government, and other nonprofit organizations.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-7.

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R&D funding reached 30%, but thereafter it declined again to an estimated 26% in 2008.

R&D Funding by Business

The business sector is both the largest performer and the largest source of R&D funding in the United States. Business provided an estimated $267.8 billion for R&D in 2008, 67% of the U.S. total.

The business sector's share of national R&D funding first surpassed the federal government's share in 1980 (figure 4-4). Almost all business funding for R&D is directed toward business R&D, with a small remainder (around 2%) allocated to academic and other nonprofit performers.

From 1980 to 1985, business support for R&D grew, in real dollars, at an average annual rate of almost 8%. From 1985 to 1994, real growth dropped to 3% per year, before expanding to 9% through 2000. Growth declined by 3% a year during the 2000–02 recession, was flat in 2003–04, and has increased robustly (5% or more real growth annually) since 2005. NSF's preliminary estimate for real growth in business-sector R&D funding in 2008 is about 6%.

R&D Funding From Other Sources

R&D funding from other nonfederal sources—academia's own institutional funds, other nonprofits, and state and local governments—is small in comparison to federal and business sources, and is estimated to have been below 7% of the total in 2008. Nonetheless, this funding has been growing fairly rapidly for some time. From 1998 to 2008, growth in funding from these sectors averaged 5.4% per year in real-dollar terms—ahead of the pace of funding growth in both the federal and business sectors. Most R&D funded by these nonfederal sources is performed by the academic sector.

Finally, unlike many countries, the United States does not currently have data on domestic R&D that is funded by foreign sources. However, NSF has begun to collect these data as part of a new business survey. Separately, foreign direct investment in R&D, which is measured in the United States, provides an indication of international participation in business R&D. However, foreign ownership does not necessarily imply foreign R&D funding, because an affiliate may fund activities through its own revenues and other domestic sources. (See "R&D by Multinational Companies.")

R&D by Character of Work

R&D encompasses a wide range of activities, from fundamental research in the physical, life, and social sciences; to research addressing such critical issues as global climate change, energy efficiency, and health care; to the development of general-purpose technologies and new goods and services. Because the activities are so diverse, it helps to classify them into distinct categories when analyzing R&D expenditures.

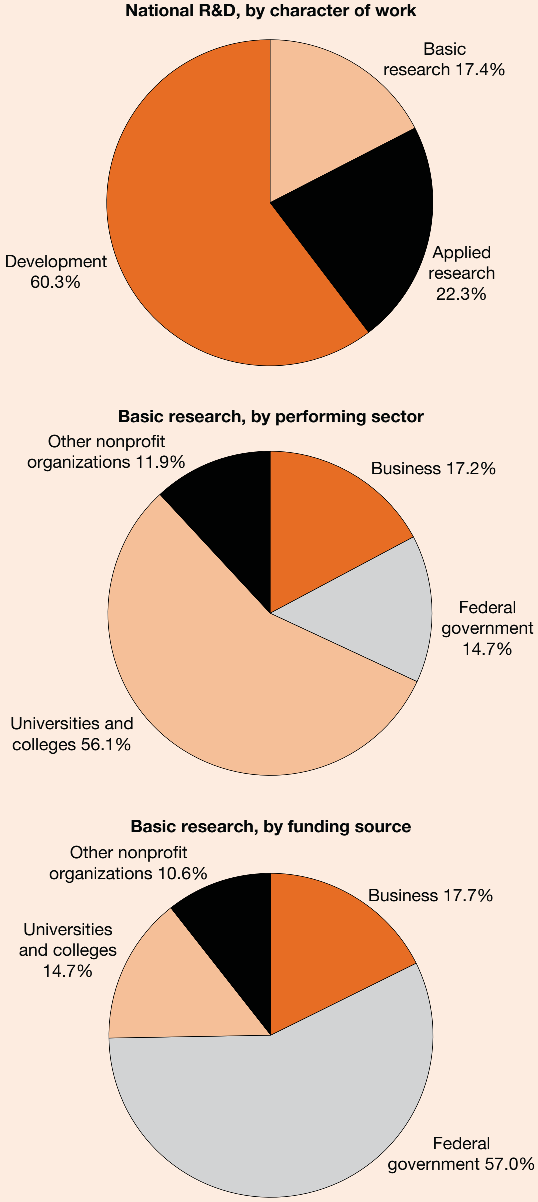
Historically, the most common categories used to classify R&D are basic research, applied research, and (experimental) development. (See sidebar "Definitions of R&D.") In light of the complex feedback loops involved in knowledge creation and exploitation, these categories have been criticized as simplistic and too linear in their implied progression. No alternative measurement frameworks, however, have been widely adopted. Accordingly, this chapter relies on these longstanding, widely used, and internationally comparable categories (OECD 2002) to describe the current trends in the character of U.S. R&D expenditures.[4]

In 2008, the United States performed an estimated $69.1 billion of basic research, $88.6 billion of applied research, and $239.9 billion of development (table 4-2). Basic research represented a little more than 17% of the total; applied research, 22%; and development, just over 60% (figure 4-5).

Historically, the federal government has been the prime source of funding for basic research, accounting for an estimated 57% of the nation's total in 2008 (figure 4-5). The share of federal funding to universities and colleges, the nation's largest performers of basic research, was 61%.

Industry directs only small portions of its R&D funding to basic research—an estimated 5% in 2008 (figure 4-6). Many businesses believe that basic research involves significant uncertainties regarding both the near-term commercial value of any discoveries and the firm's ability to enforce intellectual property rights and earn a return. Some firms, however, view engaging in basic research (whether performed internally or in cooperation with other performers) as a way to boost human capital resources by attracting and retaining talented scientists and engineers. This can strengthen the firm's capacity for innovation and improve its ability to absorb external scientific and technological knowledge. Not

Figure 4-5
National R&D, by character of work, and basic research, by funding and performing sectors: 2008



NOTES: Data for 2008 are preliminary. National R&D expenditures estimated at $398 billion in 2008. Federal performers include federal agencies and federally funded research and development centers. State and local government support to industry included in industry support for industry performance. State and local government support to universities and colleges included in universities and colleges support of universities and college performance. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3, 4-4, 4-5, 4-6, and 4-8.

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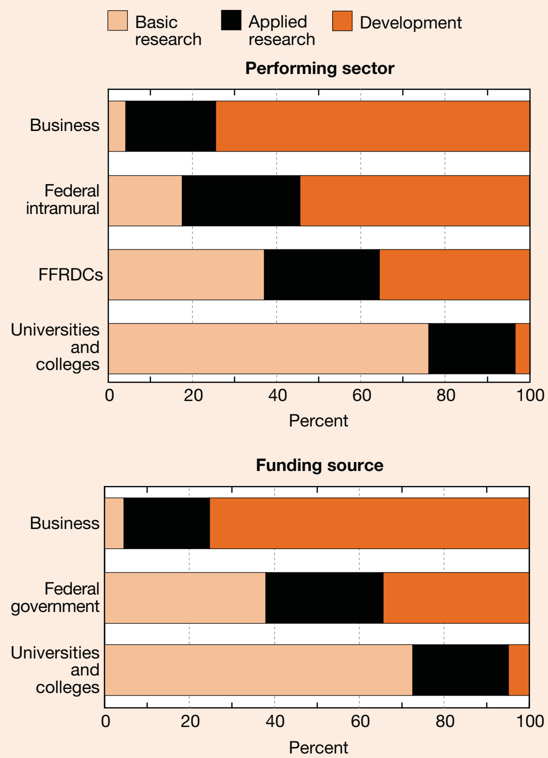
surprisingly, the industries that invest the most in basic research are those whose new products are most directly tied to ongoing science and technological advances, such as the pharmaceuticals and scientific R&D service sectors.

The business sector currently spends more than four times on applied research than basic research, accounting for greater than half of U.S. applied research funding. In 2008, industry invested an estimated $53.8 billion in applied research funding, 61% of the U.S. total. Industries that perform a relatively large amount of applied research include chemicals, aerospace (mostly funded by the Department of Defense [DOD]), and R&D services (where many companies engage in the licensing of technologies).

The bulk of the federal government's applied research funds support work that is performed by the federal agencies themselves or by FFRDCs.

Figure 4-6
R&D performing sectors and funding sources, by character of work: 2008



FFRDCs = federally funded research and development centers.

NOTES: Data for 2008 are preliminary. State and local government support to industry included in industry support for industry performance. State and local government support to universities and colleges included in universities and colleges support for universities and colleges performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 to 4-10.

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Development expenditures totaled an estimated $239.9 billion in 2008, representing 60% of all U.S. R&D expenditures.[5] The development of new and improved goods, services, and processes is dominated by the business sector, which funded 84% (an estimated $201.8 billion) of all U.S. development in 2008. The federal government funded most of the remaining development, totaling 15%, or $35.7 billion. Most federal development spending is defense related; this spending includes military aircraft, for which the federal government is the main customer.

The business sector performs a higher share of development activities than it funds, having conducted about 90% of all U.S. development in 2008. Federal agencies and FFRDCs conducted 8%, and all other performers combined conducted just below 2%.

R&D expenditures by public and private organizations indicate the priority given to the creation of new science and technology (S&T)-based knowledge in support of their goals. As an input measure, however, R&D expenditures do not directly lead to subsequent economic and social outputs. For one approach to measuring the role of R&D in economic output and growth, see the sidebar "The BEA/NSF R&D Satellite Account: R&D and Economic Growth."

Location of R&D Performance

More than half of all U.S. R&D is performed in only a few states.[6] Nonetheless, patterns of expenditures for R&D activities vary among the top R&D-performing states. (For a broader range of indicators on state-level S&E activities, see chapter 8.)

Distribution of R&D Expenditures Among States

In 2007, the 10 states with the greatest R&D expenditure levels accounted for about 64% of U.S. R&D expenditures that can be allocated to the states. The top 20 states accounted for nearly 85% of the R&D total; the 20 lowest-ranking states, around 5%. California alone represented 22% of U.S. R&D, exceeding the next-highest state, Massachusetts, by more than three times. Appendix table 4-15 provides 2007 statistics on R&D performers and funders for all the states.

To some degree, state variations in the level of R&D expenditures reflect differences in economic scale. Reporting a state's R&D expenditures as a fraction of its GDP adjusts for these differences and is an indicator of R&D intensity at the state level.

States with the highest R&D/GDP ratios in 2007 included New Mexico, Massachusetts, and Maryland (table 4-3). New Mexico is the location of several major government research facilities. Massachusetts benefits from both leading research universities and thriving high-technology industries. Maryland is the site of many government research facilities and growing research universities. California ranks seventh in R&D intensity. See appendix table 4-16 for a complete list of states and their corresponding R&D intensities.

The BEA/NSF R&D Satellite Account: R&D and Economic Growth

Measuring R&D as capital investment rather than an expense (that is, capitalizing R&D) recognizes that R&D has long-term benefits, much as do investments in physical assets. Capitalized R&D has a direct impact on GDP because business R&D becomes part of economic output instead of an expense. International activities are underway to update systems of national accounts to recognize the investment nature of R&D (UNSC 2007). A first step in the statistical systems of the United States and other OECD countries is to develop R&D satellite accounts, that is, supplementary estimates of the GDP and related measures that provide greater detail or alternative measurement concepts without changing the core accounts. Future research topics include improving the price indexes used to produce inflation-adjusted R&D investment figures and measures of the depreciation of R&D as a capital asset.

Several U.S. interagency efforts are aimed at identifying improved measures of intangibles, such as R&D, and their economic role (Aizcorbe, Moylan, and Robbins 2009; Jorgenson, Landefeld, and Nordhaus 2006). NSF's Division of Science Resources Statistics, responsible for U.S. R&D statistics, and the Bureau of Economic Analysis (BEA), responsible for the U.S. national economic accounts, are jointly developing an R&D Satellite Account (Robbins and Moylan 2007). Current plans call for incorporation of R&D capital into the National Income and Product Accounts and other core accounts in 2013.

According to BEA preliminary estimates, capitalizing R&D increased the level of current-dollar GDP by an average of 2.9% per year between 1959 and 2006. Adjusted for inflation, R&D capital would account for about 5.1% of real GDP growth between 1959 and 2006. This figure compares with a 2.2% share for all business investment in commercial and all other types of buildings. During the more recent 1995–2006 period, R&D investment accounted for about 7% of real GDP growth, with the business sector's R&D contribution amounting to 4.6% percent.

From 1995–2006, the largest estimated contributions to real GDP growth came from the pharmaceutical and medicine manufacturing industry, which accounted for more than 1% of GDP growth. The software publishing industry accounted for an additional 0.5%.

Table 4-3
Top 10 states in R&D performance, by sector and intensity: 2007

Rank	All R&D[a] State	All R&D[a] Amount (current $millions)	Sector ranking Business	Sector ranking Universities and colleges	Sector ranking Federal intramural and FFRDC[b]	R&D intensity (R&D/GDP ratio) State	R&D/GDP (%)	GDP (current $billions)
1	California	77,608	California	California	Maryland	New Mexico	7.53	75.2
2	Massachusetts	24,557	Massachusetts	New York	California	Massachusetts	6.97	352.2
3	New Jersey	19,552	New Jersey	Texas	New Mexico	Maryland	5.34	264.4
4	Texas	17,853	Michigan	Maryland	Virginia	Washington	4.85	310.3
5	Michigan	17,402	Texas	Pennsylvania	District of Columbia	Connecticut	4.82	212.3
6	New York	15,939	Washington	Massachusetts	Massachusetts	Michigan	4.58	379.9
7	Washington	15,061	Illinois	North Carolina	Tennessee	California	4.31	1,801.8
8	Illinois	14,287	New York	Illinois	Washington	New Jersey	4.24	461.3
9	Maryland	14,130	Pennsylvania	Ohio	Illinois	District of Columbia	4.17	92.5
10	Pennsylvania	13,510	Connecticut	Florida	Florida	New Hampshire	3.71	57.8

FFRDC = federally funded research and development center; GDP = gross domestic product

[a]Includes in-state total R&D performance of business, universities, federal agencies, FFRDCs, and federally financed nonprofit R&D.
[b]Includes costs associated with administration of intramural and extramural programs by federal personnel and actual intramural R&D performance.

NOTE: Small differences in parameters for state rankings may not be significant. Rankings do not account for the margin of error of the estimates from sample surveys.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2007; Survey of Research and Development Expenditures at Universities and Colleges, FY 2008; Survey of Federal Funds for Research and Development, FY 2007-2009; Survey of State Research and Development Expenditures, FY 2007. State GDP data are from the U.S. Bureau of Economic Analysis, http://www.bea.gov/regional/gsp, accessed 29 July 2009. See also appendix tables 4-15 and 4-16.

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Sector Distribution of R&D Performance by State

The proportion of R&D performed in each of the major R&D-performing sectors (business, universities and colleges, federal intramural facilities and FFRDCs) varies across states. States that lead in total R&D tend to be well represented in each of these sectors (table 4-3).

In 2007, business-sector R&D accounted for about 74% of the U.S. R&D total that could be allocated to specific states. Of the top 10 states in total R&D performance, 9 are also in the top 10 in industry R&D. Connecticut, 10th in business-sector R&D and home to substantial pharmaceutical R&D activity, surpasses Maryland in the business R&D ranking.

University-performed R&D accounts for 14% of the U.S. total, and it also closely follows state total R&D performance. Among the top 10 states in total R&D, only Michigan, New Jersey, and Washington are not also among the university R&D top 10, being replaced by North Carolina, Ohio, and Florida.

Representing about 11% of the state-distributed U.S. total, federal R&D performance (both intramural and FFRDC) is more concentrated geographically than performance in other sectors—and the relationship between its geographical distribution and that of total R&D is less significant. The top four states (Maryland, California, New Mexico, and Virginia) and the District of Columbia represent 64% of all federal R&D performance.[7] This figure rises to 78% when the other five top 10 states (Massachusetts, Tennessee, Washington, Illinois, and Florida) are included.

Federal R&D accounts for 82% of all R&D in New Mexico, home of the nation's two largest FFRDCs (Los Alamos and Sandia National Laboratories). The high figures for Maryland (54%), Virginia (38%), and the District of Columbia (74%) reflect the concentration of federal facilities and administrative offices in the national capital area. The share for Tennessee (32%) reflects the presence of a large federal facility, Oak Ridge National Laboratory.

In California, Massachusetts, Washington, and Illinois, federal R&D performance accounts for no more than 6% to 7% of the state R&D totals, even though each state is among the top 10 in federal performance. The federal R&D share in Florida was 13% in 2007.

Business R&D in Top States

During 2007, companies in the 10 states with the highest business R&D performance reported aggregate R&D expenditures of $186.0 billion and accounted for 69% of the business R&D performed in the United States. Companies in California alone accounted for 24% of the nation's business R&D. The types of companies that carry out R&D vary considerably among these 10 leading states (table 4-4), reflecting regional specialization or clusters of business activity. For example, the automotive manufacturing industry accounted for 75% of Michigan's business R&D in 2007, although it accounted for only 6% of the nation's total business R&D.

Table 4-4
Top 10 states in business R&D performance and share of R&D, by selected industry: 2007
(Percent)

State	Business-performed R&D (current $millions)	Chemicals	Computer and electronic products	Computer-related services	R&D services	Motor vehicles	Companies with 5–499 employees
All states	269,267	20.6 L	21.8	5.4	8.4	6.0 L	18.7
California	64,187	13.9	33.0	14.6	9.5	D	20.2
Massachusetts	19,488	17.4	44.6	5.5	9.9	0.0	18.5
New Jersey	17,892	63.1	6.3	5.2	8.0	0.1	13.4
Michigan	15,736	6.7	1.3	1.9	2.8	74.8	8.5
Texas	13,889	5.6	32.3	17.8	7.4	0.4	18.6
Washington	12,687	5.2	5.3	2.6	6.5	0.4	12.3
Illinois	11,362	25.2	32.7	4.3	2.4	1.8	14.1
New York	10,916	30.1	7.8	15.6	4.1	3.0	22.7
Pennsylvania	10,387	55.0	7.3	6.2	5.2	0.8	17.5
Connecticut	9,444	59.0	2.3	2.5	3.2	0.2	8.2

L = lower-bound estimate; D = suppressed to avoid disclosure of confidential information

NOTES: Rankings do not account for margin of error of estimates from sample surveys. Detail does not add to total because not all industries shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development.

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The computer and electronic product manufacturing industries performed 22% of the nation's total business R&D, but the shares of this performance were larger in Massachusetts (45%), Illinois (33%), California (33%), and Texas (32%). These states have clearly defined regional centers of high-technology research and manufacturing, including Cambridge and Route 128 in Massachusetts; Champaign County, Illinois; Silicon Valley, California; and the Silicon Hills of Austin. About two-thirds of R&D performed in the United States by computer and electronic product companies in 2007 was located in these four states and accounted for 14% of all business R&D nationwide (table 4-4; appendix table 4-11).

R&D performed by chemical manufacturing companies remains prominent in New Jersey, Connecticut, and Pennsylvania, all home to the pharmaceuticals and the chemicals industries. According to the American Chemistry Council (ACC 2009), together these states are host to more than 2,000 chemical manufacturing establishments, an increase of about 500 since 2005, and rank among the top 18 in chemicals industry employment. In 2007, chemical manufacturers accounted for 63% of New Jersey's business R&D, 59% of Connecticut's, and 55% of Pennsylvania's (table 4-4). These three states represented more than 41% of the nation's R&D in this sector.

The R&D and related-services sector, which consists largely of biotechnology companies, contract research organizations, and early-stage technology firms, is also geographically concentrated, with California, Massachusetts, and New Jersey accounting for more than 42% of R&D. The companies in this sector maintain strong ties to the academic sector and are often located near large research universities (Stuart and Sorenson 2003).

Nationally, small companies (those that have from 5 to 499 employees[8]) performed 19% of total U.S. business R&D in 2007 (appendix table 4-11). Among the top 10 business R&D-performing states, New York and California had the highest totals of small companies performing business R&D, with 23% and 20%, respectively, in each state. Small companies in these two states performed 6% of the nation's total business R&D in 2007 (table 4-4).

Business R&D

Businesses perform R&D with a variety of objectives in mind, but most business R&D is aimed at developing new and improved goods, services, and processes. R&D expenditures, therefore, indicate the level of effort dedicated to producing future products and process improvements while maintaining current market share and increasing operating efficiency. By extension, such expenditures may reflect firms' perceptions of the market's demand for new and improved technology.

R&D performed by the business sector totaled $269.3 billion in 2007. The federal government funded 9.9% ($26.6 billion) of this total, and company funds and other private sources financed the remainder (appendix tables 4-11 to 4-13).[9]

In addition to absolute levels of R&D expenditures, another indicator in the business sector is R&D intensity—that is, R&D relative to production in a company, industry, or sector. The measure used most frequently is the ratio of company-funded R&D to net sales.[10] This statistic provides a way to gauge the relative importance of R&D across industries and among firms in the same industry. The company-funded R&D-to-sales ratio of companies in all industries performing R&D in the United States varied between 3.2% and 3.4% during 2003-06; in 2007 it was 3.5% (table 4-5; appendix table 4-14).

Largest R&D Industries

Benefits from advances in S&T may be broadly shared among industries; however, different industries perform different amounts of R&D.[11] Some industries, such as utility,[12] finance, insurance, and real estate, have relatively low R&D intensities (0.5% or less). Appendix table 4-14 provides data on ratios of company-funded R&D to net sales for an array of industries.[13] Six industry groups—four in manufacturing (chemicals, computer and electronic products, aerospace and defense manufacturing, and automotive manufacturing) and two in services (software and computer-related, and R&D services)—accounted for 78% of company-funded business R&D and 95% of federally funded business R&D in 2007 (table 4-5).[14]

Table 4-5
Business R&D and domestic net sales, by industry: 2006 and 2007
(Millions of current dollars)

Industry	Business-performed R&D 2006	Business-performed R&D 2007	Federally funded R&D 2006	Federally funded R&D 2007	Company-funded R&D 2006	Company-funded R&D 2007
All	247,669	269,267	24,304	26,585	223,365	242,682
Highlighted industries	193,956 L	209,116 L	23,352 L	25,355 L	170,606	183,761
Chemicals	48,913	50,423	662	663	48,251	49,760
Computer and electronic products[a]	46,329	55,571 L	211	252 L	46,119	55,319
Software and computer-related services[b]	33,831 L	34,079 L	1,048 L	842	32,783	33,237
Aerospace and defense manufacturing[c]	27,217 L	30,278 L	15,222 L	16,882 L	11,995	13,397
R&D and related services[d]	21,104	22,731	6,209	6,716	14,896	16,014
Automotive manufacturing[e]	16,562 L	16,034 L	NA	NA	16,562	16,034
All other	53,713 L	60,151 L	952 L	1,230 L	52,759	58,921

Industry	Domestic net sales 2006	Domestic net sales 2007	Business-performed R&D/sales ratio (%) 2006	Business-performed R&D/sales ratio (%) 2007	Company-funded R&D/sales ratio (%) 2006	Company-funded R&D/sales ratio (%) 2007
All	6,642,500	7,027,049	3.7	3.8	3.4	3.5
Highlighted industries	2,530,579	2,602,127	7.7	8.0	6.7	7.1
Chemicals	524,160	589,918	9.3	8.5	9.2	8.4
Computer and electronic products[a]	612,885	699,520	7.6	7.9	7.5	7.9
Software and computer-related services[b]	376,638	304,952	9.0	11.2	8.7	10.9
Aerospace and defense manufacturing[c]	243,110	263,321	11.2	11.5	4.9	5.1
R&D and related services[d]	86,945	89,166	24.3	25.5	17.1	18.0
Automotive manufacturing[e]	686,841	655,250	2.4	2.4	2.4	2.4
All other	4,111,921	4,424,922	1.3	1.4	1.3	1.3

L = lower-bound estimate; NA = not available

[a]Includes all R&D and domestic net sales for the computer and electronics industry (NAICS 334), except for federal R&D for the navigational, measuring, electromedical, and control instruments industry (NAICS 3345), which is included in the aerospace and defense manufacturing sector.
[b]Includes R&D and domestic net sales for software (NAICS 5112) and computer systems design and related service industries (NAICS 5415).
[c]Includes all R&D for aerospace products and parts (NAICS 3364), plus all federal R&D for navigational, measuring, electromedical, and control instruments (NAICS 3345), automotive (NAICS 3361–3363), and other transportation manufacturing industries. Domestic net sales are not included for automotive and other transportation manufacturing industries.
[d]Includes R&D and domestic net sales for architectural, engineering, and related services (NAICS 5413) and scientific R&D services industries (NAICS 5417).
[e]Includes all R&D for transportation manufacturing equipment (NAICS 336), except federally funded components that are included in aerospace and defense manufacturing sector.

NOTE: Potential disclosure of individual company operations only allows lower-bound estimates for some sectors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development.

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Chemicals (Including Pharmaceuticals)

Among three-digit North American Industry Classification System (NAICS) codes, the chemicals industry accounted for the largest amount of R&D performed in the United States in 2007. Companies in this group performed $55.6 billion of R&D, with relatively little of it federally funded. Within the chemicals industry, the largest subsector is pharmaceuticals and medicines. In 2007, pharmaceutical companies performed $47.6 billion of company-funded R&D, representing 86% of nonfederal R&D funding in the chemicals sector (appendix table 4-12).

A related indicator is reported by the Pharmaceutical Research and Manufacturers of America (PhRMA), an industry association that represents the country's leading research-based pharmaceutical and biotechnology companies. This association conducts an annual survey of its members to gather information about R&D. In 2007, PhRMA estimated that its members invested $35.4 billion in R&D performed in the United States and $9.1 billion in R&D performed abroad. The total $44.5 billion investment represented 18.7% of domestic sales and 16.4% of global sales (PhRMA 2008a).[15] According to PhRMA, U.S. biopharmaceutical research companies obtained approval for 26 new medicines in 2007 from the U.S. Food and Drug Administration. About 75% of PhRMA members' domestic R&D investment supports R&D on projects that originate in their own laboratories, and 25% supports R&D on products licensed from other organizations, notably biotechnology companies, universities, or the government (PhRMA 2008b).[16]

Computer and Electronic Products

Companies in the computer and electronic product manufacturing industry include producers of computers, computer peripherals, communications equipment, and similar electronic products and producers of components for such products.[17] The design and use of integrated circuits and the application of highly specialized miniaturization technologies are common elements in the production processes of the computer and electronic product sector.

In 2007, companies in this industry performed $50.4 billion of R&D, or 19% of all business R&D (table 4-5).[18] Company and other nonfederal sources funded almost all of this R&D. Two of the more R&D-intensive industries, communications equipment and semiconductor manufacturing, are included in this group. Both devoted more than 10% of sales to R&D in 2007 (appendix table 4-14).

Software and Computer-Related Services

Software and computer-related services industries, such as data processing and computer systems design, performed approximately $33.2 billion of company-funded R&D in 2007. The R&D of these industries (14% of the U.S. business sector total), combined with that of the computer and electronic product manufacturers, accounted for 34% of all industrial R&D in 2007. As computing and information technology has become more integrated with every sector of the economy, the demand for services associated with these technologies has increased.

Between 1987 and 2007, R&D expenditures of companies providing these services grew. In 1987, when an NSF survey estimate of software and other computer-related services R&D first became available, companies classified in the industry group—computer programming, data processing, other computer-related, engineering, architectural, and surveying services—performed $2.4 billion of company-funded R&D, or 3.8% of all company-funded industrial R&D. In 2007, the company-funded R&D of these industries (excluding engineering and architectural services) accounted for 13.7% of all company-funded industrial R&D, and these companies accounted for 4.3% of domestic sales of R&D-performing companies (table 4-6).[19]

Table 4-6
Estimated share of computer-related services in company-funded R&D and domestic net sales of R&D-performing companies: 1987–2007
(Percent)

Year	Company-funded R&D	Domestic net sales
1987	3.8	1.4
1988	3.6	1.5
1989	3.4	1.4
1990	3.7	1.5
1991	3.6	1.6
1992	4.0	1.6
1993	8.2	1.5
1994	6.6	2.2
1995	8.8	3.3
1996	8.8	2.6
1997	9.1	2.5
1998	9.5	2.2
1999	10.6	2.2
2000	10.9	2.8
2001	13.0	3.5
2002	14.6	5.4
2003	14.3	3.5
2004	14.7	3.0
2005	14.7	3.5
2006	14.7	5.7
2007	13.7	4.3

NOTES: Before 1998 companies classified in Standard Industrial Classification (SIC) industries 737 (computer and data processing services) and 871 (engineering, architectural, and surveying services). After 1998 companies classified in North American Industry Classification System (NAICS) industries 5112 (software) and 5415 (computer systems design and related services). With SIC classification, information technology services share of company-funded R&D was 10.4% for 1998, indicating SIC-based data may overestimate information technology services R&D and net sales relative to NAICS-based data.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series), http://www.nsf.gov/statistics/srvyindustry/, accessed 6 May 2009.

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Aerospace and Defense Manufacturing

Although it is common to refer to the “defense industry,” the NAICS industry classification system does not include this category. Thus, to approximate the cost of defense-related R&D, one can focus on aerospace products and parts, plus federally funded R&D in the following industries: navigational, measuring, electromedical, and control instruments; automotive manufacturing; and other transportation manufacturing industries. Companies in this sector perform the majority of DOD’s extramural R&D. In 2007, these industries reported performing $16.9 billion of federally funded R&D (table 4-5), about 64% of all federally funded industrial R&D. This total accounts for more than half of the $30.3 billion that the defense industry as a whole spent on R&D, including both federal and nonfederal sources of funds. (See “Federal R&D” for further discussion of defense R&D.)

R&D and Related Services

The R&D and related-services category includes companies that provide scientific R&D, engineering, and architectural services to other firms. Also included are businesses that conduct R&D for their own use (e.g., biotechnology and other firms that conduct R&D in physical, engineering, and life sciences) but may not yet have sales. Companies in this sector performed $6.7 billion of federally funded R&D in 2007, the highest figure outside the aerospace and defense manufacturing category. Despite the significant amount of government-sponsored R&D performed by this sector, R&D and related-services companies increasingly rely on nonfederal sources of R&D financing. The R&D performed by companies in the R&D and related-services sector and funded by company and other nonfederal sources has grown from $5.8 billion in 1997 to $16 billion in 2007.[20] Because much of the R&D reported by these companies also appears in their reported sales figures, the R&D intensity of this sector is particularly high (26% in 2007).[21]

Automotive Manufacturing

The sixth-largest business sector in terms of R&D is automotive manufacturing. Companies in this industry reported performing $16 billion of company-funded R&D in 2007, accounting for 6% of all such R&D performed by businesses in the United States.

In 2007, 15 companies in the automotive manufacturing industry reported company-funded R&D expenditures of more than $100 million each, collectively representing 83% of the industry’s R&D (NSF/SRS 2009). In most industries, large companies perform more R&D than small companies, but in the automotive manufacturing industry, the distribution of R&D is even more skewed toward large companies, with the R&D activities of General Motors, Ford, and DaimlerChrysler dominating the sector. In their reports to the Securities and Exchange Commission, these companies noted R&D expenses of $20.8 billion in 2006 (IEEE 2009). In addition to NSF statistics, other sources of indicators for business R&D include surveys conducted by the Industrial Research Institute (IRI) and companies’ own annual reports. (See sidebar “Trends in R&D for Industrial Research Institute Members.”[22])

Federal R&D

The government supports S&T through a number of policy measures, the most direct of which is the conduct and funding of R&D that would not or could not be conducted or financed in the private sector. This section presents data on federally funded R&D activities, on the government’s contribution to the U.S. R&D infrastructure, and on federal R&D tax credits, which serve as an indirect means of stimulating R&D in the private sector.

Trends in R&D for Industrial Research Institute Members

For more than 20 years, the Industrial Research Institute (IRI), a nonprofit association of more than 200 leading, R&D-performing, manufacturing and service companies, has surveyed its U.S.-based members on their intentions for the coming year with respect to R&D expenditures, focus of R&D, R&D personnel, and other items. Because IRI member companies carry out a large amount of industrial R&D in the United States, the results of these surveys help identify broad trends in corporate R&D strategies.

The most recent survey, administered during the summer of 2008, suggests that many companies continue to shift the focus of their R&D spending away from directed basic research and the support of existing business to new business projects (IRI 2009). As reflected in IRI’s Sea Change Index,* IRI survey respondents also reported the following plans and expectations for 2009:

- Increase outsourcing of R&D to other companies
- Increase outsourcing to universities and participation in academic consortia
- Increase outsourcing to federal laboratories
- Increase participation in alliances and joint R&D ventures
- Increase acquisition of technological capabilities through mergers and acquisitions
- Increase spin-offs based on developed technology
- Maintain total company expenditures for R&D
- Maintain level of technology licensing to others

Overall, these strategic moves are consistent with companies’ expectations of flat R&D budgets.

*IRI states that its Sea Change Index likely “understates the absolute value of change,” but the association believes it to be a “good indicator of the direction of change.” See IRI (2009) for details.

R&D Funding in Current Federal Budget

The budget appropriations for federal spending on R&D in FY 2009 (signed into law in March 2009) totaled $147.1 billion (table 4-7), an increase of $3.3 billion, or 2.3%, over the enacted FY 2008 spending level of $143.7 billion. The president's proposed FY 2010 budget includes requests for spending on R&D of $147.6 billion, an increase of $0.6 billion, or 0.4%, over the appropriated FY 2009 level.

In addition, a one-time but sizable increase in budget authority for federal R&D was provided by the American Recovery and Reinvestment Act (ARRA) (Public Law 111-5) in early 2009. In a preliminary estimate (May 2009), the White House's Office of Science and Technology Policy placed the overall increase of federal R&D and R&D infrastructure funding from ARRA at about $18.3 billion in FY 2009 (table 4-7).

Adjusted for inflation, the enacted federal budget for FY 2009 represents a 0.8% increase in constant dollars. The increase proposed by the president for FY 2010 represents a constant-dollar decline of 0.6%. The ARRA funding is a sizable increase, whether in current-dollar or inflation-adjusted

Table 4-7
Federal budget authority for R&D and R&D plant: FY 2008–10
(Millions of current dollars)

Performer/character of work	FY 2008 Actual	FY 2009 Enacted	FY 2009 ARRA[a]	FY 2010 Requested	Annual change (%)[b] 2008–09	Annual change (%)[b] 2009–10
All R&D, R&D facilities and equipment	143,746	147,065	18,335	147,620	2.3	0.4
DOD (military)	82,278	81,616	300	79,687	–0.8	–2.4
HHS	29,265	30,415	11,103	30,936	3.9	1.7
NIH	28,547	29,748	10,400	30,184	4.2	1.5
All other HHS R&D	718	667	703	752	–7.1	12.7
NASA	11,182	10,401	925	11,439	–7.0	10.0
DOE	9,807	10,621	2,446	10,740	8.3	1.1
NSF	4,580	4,857	2,900	5,312	6.0	9.4
USDA	2,336	2,421	176	2,272	3.6	–6.2
DOC	1,160	1,292	411	1,330	11.4	2.9
NOAA	625	700	1	644	12.0	–8.0
NIST	498	550	410	637	10.4	15.8
VA	960	1,020	0	1,160	6.3	13.7
DHS	995	1,096	0	1,125	10.2	2.6
DOT	875	913	0	939	4.3	2.8
DOI	683	692	74	730	1.3	5.5
USGS	586	611	74	649	4.3	6.2
EPA	551	580	0	619	5.3	6.7
ED	313	323	0	384	3.2	18.9
All other	761	818	0	947	7.5	15.8
Research	56,026	58,647	13,285	59,023	4.7	0.6
Basic	28,613	29,881	11,365	30,884	4.4	3.4
Applied	27,413	28,766	1,920	28,139	4.9	–2.2
Development	83,254	83,887	1,408	84,054	0.8	0.2
R&D facilities and equipment	4,466	4,531	3,642	4,543	1.5	0.3
Defense R&D	84,337	85,426	300	83,760	1.3	–2.0
Nondefense R&D	59,409	61,639	18,035	63,860	3.8	3.6
All R&D, R&D facilities and equipment (2000 constant $millions)	117,286	118,267	14,745	117,532	0.8	–0.6

ARRA = American Recovery and Reinvestment Act; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; ED = Department of Education; EPA = Environmental Protection Agency; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NIH = National Institutes of Health; NIST = National Institute of Standards and Technology; NOAA = National Oceanic and Atmospheric Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; USGS = U.S. Geological Survey; VA = Department of Veterans Affairs

[a]Based on preliminary allocations of ARRA. These figures may change.
[b]Excludes appropriations from ARRA. Change is FY 2008 actual appropriations to FY 2009 enacted appropriations; FY 2009 enacted appropriations to FY 2010 requested appropriations.

SOURCES: Office of Management and Budget, Budget of the United States Government for Fiscal Year 2010, 7 May 2009; and Office of Science and Technology Policy, Executive Office of the President, Federal R&D, Technology, and STEM Education in the 2010 Budget, 7 May 2009.

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terms. The overall effects on the growth of federal R&D funding in either year depends on whether added spending under ARRA occurs in FY 2009 or FY 2010.

The largest increases among the agencies in the FY 2009 budget for R&D go to the National Institutes of Health (NIH), with an increase of $1.2 billion; the Department of Energy (DOE), up $814 million; and NSF, up $277 million (table 4-7). These same agencies are also major recipients of ARRA funds (table 4-7): $10.4 billion to NIH for added biomedical research and laboratory renovation and construction; $2.9 billion to NSF for increased basic research, education and human resources, research facility construction, and research instrumentation; and $2.4 billion to DOE for new collaborations at the frontiers of energy research and infrastructure investments at the national laboratories. In addition, $925 million goes to the National Aeronautics and Space Administration (NASA) for accelerated activities in earth science climate research missions and the development of a next-generation air transport system. Another $410 million goes to the National Institute of Standards and Technology (NIST) for new standards research, advanced measurement equipment, and construction of research facilities.

The president's FY 2010 proposal for federal R&D notes investment priorities in four main areas, as follows:

- Sciences for a prosperous America—increased federal support for basic research. This focus recognizes that new fundamental knowledge and technology have often fueled the creation of new industries with associated high-technology and high-wage jobs.
- A clean energy future—expanded investment in research, development, demonstration, and deployment of clean energy technologies to help reduce U.S. dependence on oil, create green jobs, and limit the impact of climate change. (See sidebar "Public Investment in Energy R&D.")
- Healthy lives for all Americans—increased funding for biomedical and health research.
- A safe and secure America—development of better science and technology to improve the prediction and prevention of, and the reaction to, destabilizing or paralyzing natural and man-made threats; improve capabilities for biodefense; and monitor nuclear nonproliferation compliance and prevent the surreptitious entry of weapons of mass destruction (OSTP 2009).

Federal R&D Budget by National Objectives

To assist Congress and the president in evaluating and setting the federal budget and its components, the Office of Management and Budget classifies agency budget requests into specific categories called *budget functions*. Budget functions represent a wide range of national objectives that the government wants to advance, from defense to health to transportation.

Defense-Related R&D

In the FY 2008 budget, defense was the largest budget function, accounting for $81.1 billion (current dollars), or 59% of the federal R&D budget (appendix table 4-17). Nondefense functions totaled $56.9 billion. Defense R&D is supported by DOD, DOE, and the Department of Homeland Security (DHS), with DOD accounting for $78 billion in FY 2008.

The proportional split between defense and nondefense R&D has fluctuated over the past several decades (figure 4-7). In FY 1980, federal budget authority for defense-related R&D roughly equaled nondefense R&D. During the next several years, however, defense R&D expanded rapidly. By FY 1985, defense R&D budget authority more than doubled that of nondefense R&D. In contrast, between 1986 and 2001 nondefense surged, and the gap between defense and nondefense R&D budgets shrank almost every year. In FY 2001, the defense budget function represented 53% of the federal R&D budget. The trend reversed yet again after September 11, 2001, as defense R&D became more prominent, accounting for 59% of the federal R&D budget in FY 2008.

Civilian-Related R&D

The most dramatic change in federal R&D priorities over the past 25 years has been the increase in health-related R&D (figure 4-7), which rose from 25% of the federal nondefense R&D budget allocation in FY 1980 to 55% in FY 2005. Growth accelerated after 1998, when policymakers set the NIH budget on course to double by FY 2003. In FY 2008, health-related R&D represented 52% of nondefense R&D, even though recent increases have been below the level of inflation.

The budget allocation for space-related R&D peaked in the 1960s, during the height of the nation's efforts to surpass the Soviet Union in space exploration. The loss of the Space Shuttle *Columbia* and its entire crew in February 2003 prompted curtailment of manned space missions. In more recent years, NASA's nondefense R&D budget share has increased, growing from 14% in FY 2005 to 17% in FY 2008. Nearly 58% of NASA's $17 billion budget in FY 2008 was allocated for R&D; adjusted for inflation, the space-related R&D total was higher in FY 2008 than at any time since FY 1999.

Federal nondefense R&D classified as general science had about a 9% share in the mid 1990s, growing to 14% in FY 2008. However, this change reflected chiefly a reclassification of several DOE programs from energy to general science in FY 1998.

With respect to the federal budget for basic research, 94% of the funding in FY 2008 resided in nondefense budget functions (appendix table 4-18). In large part, this reflects the budgets of agencies with nondefense objectives such as general science (notably NSF), health (NIH), and space research and technology (NASA). Over the past several years, budget authority for basic research (which is not equivalent to general science R&D) has been flat after adjusting for inflation.

Public Investment in Energy R&D

International public investment in energy research, development, and demonstration (hereafter R&D) has grown by about 30% over the 1997–2007 period, from $8.6 billion to $11.3 billion in inflation-adjusted dollars (figure 4-A). The data reflect annual energy R&D reports, by technology type, submitted by member governments of the International Energy Agency (IEA). These data provide insight into governmental R&D priorities in this area. The data do not include industry-funded activities in the listed energy types, nor do they cover broader activities that seek energy savings or reductions in such areas as industrial production and automotive and aircraft design.

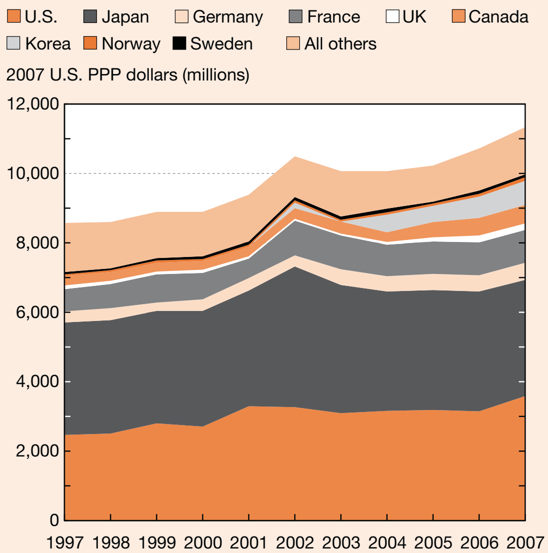
The U.S. and Japanese governments reported by far the largest energy R&D government funds, fluctuating around 30% of the reported IEA total for the United States and declining from 38% to 30% for Japan. France, Germany, and the United Kingdom, which are very broadly similar in overall R&D spending, committed very different public investments to energy R&D, with France's funding being much larger than expected relative to the other two countries. South Korea invested more than the combined total of the United Kingdom and Germany.

The biggest energy type is nuclear fission and fusion (figure 4-B), which consumed 38% of the 2007 amount—down from 48% in 1997—and showed share losses in many major countries: from 75% to 65% in Japan, from 92% to 60% in France, and from 56% to 33% in Germany. In the United States, the energy share of nuclear fission/fusion rose from a low of 10% in 2002 to 18% in 2007—still well below the level of most other major countries.

R&D in hydrogen and fuel cell energy is of most recent vintage. It represented about 7% of the IEA 2007 total; Canada stood out with 16% of its energy R&D funds in hydrogen and fuel cell technology. R&D in renewable energy has slowly risen to about 12% of the total, from 8% a decade ago; the United Kingdom led in renewable energy, with an increase from 9% to 36%; Sweden's level was high at 33%, as was Germany's at 22%.

The quest for energy efficiency received a fairly steady 13% of total energy R&D budgets, although the budget share was less in Germany, France, and the United Kingdom. All other technologies combined averaged about 20% but garnered twice that level in the United States and much less than the IEA average in Japan and France.

Figure 4-A
Energy R&D budgets of national governments of selected IEA members: 1997–2007



IEA = International Energy Agency; PPP = purchasing power parity; R&D = research, development, and demonstration

SOURCE: IEA, http://wds.iea.org, accessed 31 July 2009.

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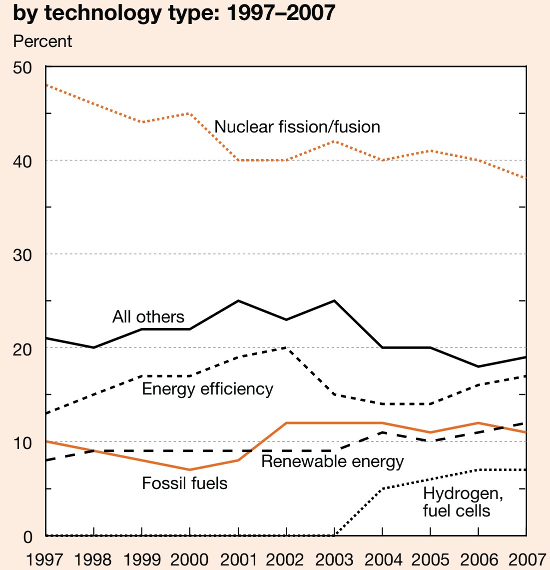
Figure 4-B
Combined energy R&D budgets of IEA members, by technology type: 1997–2007



IEA = International Energy Agency; R&D = research, development, and demonstration

NOTE: Percentage of totals reported by all IEA members.

SOURCE: IEA, http://wds.iea.org, accessed 31 July 2009.

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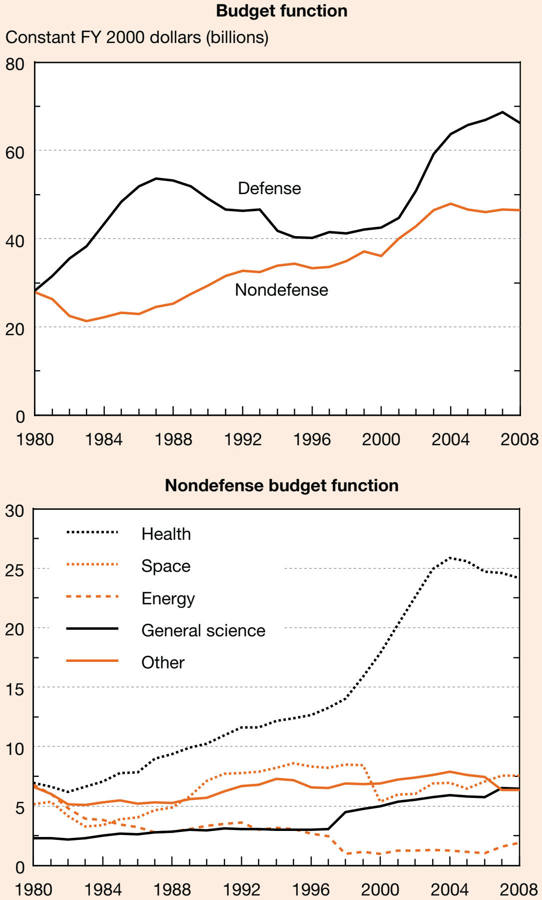
Figure 4-7
Federal R&D budget authority, by budget function: FY 1980–2008



NOTES: Figures for FY 2008 are preliminary. Other includes all nondefense functions not separately graphed, such as agriculture and transportation. 1998 increase in general science and decrease in energy, and 2000 decrease in space were results of reclassification.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal R&D Funding by Budget Function: Fiscal Years 2007–09. See appendix table 4-17.

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In FY 2003, basic research budget authority was $23.8 billion (constant 2000 dollars); in FY 2008, $23.4 billion.

Federal Spending on R&D by Agency

Federal R&D obligations totaled an estimated $114.6 billion in FY 2008 (the most recent year for which complete data are available). An additional $1.8 billion was obligated for R&D plant (facilities and equipment). Federal obligations for R&D have increased annually on a current-dollar basis since the early 1990s, but when adjusted for inflation, the increases flatten out after FY 2005 (appendix table 4-19).

More than 20 federal agencies fund R&D in the United States. In FY 2008, seven agencies committed more than $1 billion each for R&D (figure 4-8; table 4-8; table 4-9; appendix table 4-20). These agencies accounted for about 96% of total federal R&D obligations that year.

Department of Defense

DOD funds more than half of all federal R&D, having provided an estimated $58.7 billion (51%) in FY 2008. Of this total, $51.8 billion, or 88%, went to development, the majority ($45.8 billion) being allocated for "major systems development," which includes the primary activities for developing, testing, and evaluating combat systems.

Extramural performers received 71% of DOD's R&D obligations ($41.8 billion), the bulk going to industrial firms ($38.6 billion). DOD accounted for about 84% of all federal R&D funding to industry in FY 2008. DOD intramural R&D accounted for 26%, and FFRDC R&D accounted for 3%.

Department of Health and Human Services

The Department of Health and Human Services (HHS) is the primary federal source of funding for health-related R&D. In FY 2008, it obligated an estimated $29.7 billion, or 26% of all federal R&D, most ($28.5 billion) being R&D funding by NIH. HHS R&D funding is almost entirely allocated for research (almost 54% for basic and 46% for applied). Development activities accounted for less than 1% of the HHS total.

Extramural performers accounted for 80% ($23.8 billion) of FY 2008 HHS R&D obligations. Universities and colleges received $17.1 billion; other nonprofit research organizations, $4.4 billion. HHS provided about 67% of all federal R&D funds distributed to universities and colleges in FY 2008 and 74% of federal R&D funds distributed to nonprofit institutions.

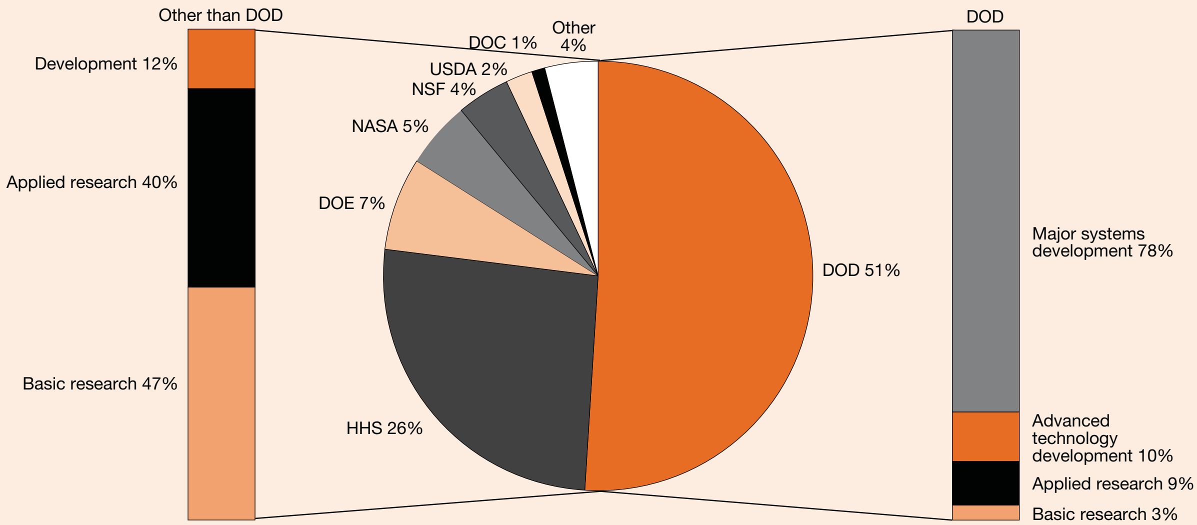
Department of Energy

DOE obligated an estimated $8.2 billion to R&D in FY 2008, 7% of the federal R&D total. Research accounted for 76% of these obligations (40% for basic and 36% for applied). FFRDCs received about 66% of DOE R&D obligations. Many of DOE's research activities require specialized equipment and facilities available only at its intramural laboratories and FFRDCs. Accordingly, DOE invests more resources in FFRDCs than other agencies. In FY 2008, DOE funds accounted for 59% of all federal R&D obligations to FFRDCs.

National Aeronautics and Space Administration

NASA obligated an estimated $6.2 billion to R&D in FY 2008, 5% of the federal R&D total. Of this R&D support, 66% funded development activities; 21%, basic research; and 13%, applied research. Extramural R&D (chiefly by industry performers) accounted for 64% of NASA's R&D obligations in FY 2008. Agency intramural activities represented 19%—and FFRDC activities, another 17%—of the NASA R&D total.

Figure 4-8
Projected federal obligations for R&D, by agency and character of work: FY 2008



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

NOTE: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–09. See appendix table 4-30.

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Table 4-8
Federal obligations for research and development, by agency and character of work: FY 2008
(Millions of current dollars)

Agency	Obligations for total R&D	Basic research	Applied research	Development	Basic research (%)	Applied research (%)	Development (%)
All federal government	114,625	27,559	27,538	59,528	24.0	24.0	51.9
DOD	58,676	1,510	5,345	51,821	2.6	9.1	88.3
HHS	29,657	15,989	13,594	74	53.9	45.8	0.2
DOE	8,212	3,243	2,917	2,052	39.5	35.5	25.0
NASA	6,243	1,298	829	4,117	20.8	13.3	65.9
NSF	4,031	3,692	340	0	91.6	8.4	0.0
USDA	2,357	990	1,197	170	42.0	50.8	7.2
DOC	1,062	108	861	93	10.2	81.1	8.8
DOT	885	3	638	245	0.3	72.0	27.7
DHS	847	191	77	579	22.5	9.1	68.3
DOI	625	43	513	68	6.9	82.1	10.9
EPA	557	97	379	81	17.4	68.1	14.5
VA	480	211	246	23	44.0	51.2	4.8
ED	325	4	202	119	1.3	62.0	36.7
Smithsonian Institution	148	148	0	0	100.0	0.0	0.0
AID	138	6	132	0	4.1	95.9	0.0
All other	382	26	270	86	6.9	70.6	22.5

AID = Agency for International Development; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; ED = Department of Education; EPA = Environmental Protection Agency; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; VA = Department of Veterans Affairs

NOTES: Table lists all agencies with R&D obligations greater than $100 million in FY 2008. Figures for FY 2008 are preliminary.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–09.

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Table 4-9
Federal obligations for research and development, by agency and performer: FY 2008
(Millions of dollars)

Agency	Obligations for total R&D	Agency intramural	FFRDCs	Extramural performers	Agency intramural (%)	FFRDCs (%)	Extramural performers (%)
All federal government	114,625	26,828	9,171	78,627	23.4	8.0	68.6
DOD	58,676	15,066	1,770	41,840	25.7	3.0	71.3
HHS	29,657	5,287	527	23,843	17.8	1.8	80.4
DOE	8,212	678	5,400	2,135	8.3	65.8	26.0
NASA	6,243	1,198	1,077	3,969	19.2	17.2	63.6
NSF	4,032	16	207	3,808	0.4	5.1	94.5
USDA	2,357	1,497	0	860	63.5	0.0	36.5
DOC	1,062	830	1	231	78.2	0.1	21.7
DOT	885	250	17	618	28.3	1.9	69.8
DHS	847	225	148	475	26.6	17.4	56.0
DOI	625	532	0	93	85.2	0.0	14.8
EPA	557	407	0	150	73.1	0.0	26.9
VA	480	480	0	0	100.0	0.0	0.0
ED	325	13	0	312	4.0	0.0	96.0
Smithsonian Institution	148	148	0	0	100.0	0.0	0.0
AID	138	17	0	121	12.5	0.0	87.5
All other	382	183	25	174	47.9	6.5	45.7

AID = Agency for International Development; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; ED = Department of Education; EPA = Environmental Protection Agency; FFRDC = federally funded research and development center; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; VA = Department of Veterans Affairs

NOTES: Table lists all agencies with R&D obligations greater than $100 million in FY 2008. Figures for FY 2008 are preliminary. Total R&D is basic research, applied research, and development; does not include R&D plant. Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by federal personnel. Extramural performers includes federally funded R&D performed in the United States and U.S. territories by industry, universities and colleges, other nonprofit institutions, state and local governments, and foreign organizations.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–09.

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National Science Foundation

NSF obligated an estimated $4 billion for research in FY 2008. About 92% of NSF's support funded basic research, and 95% funded extramural performers, chiefly universities and colleges ($3.3 billion). NSF is the federal government's primary source of funding for academic, basic S&E research and the second-largest federal source (after HHS) of R&D funds for universities and colleges.

Department of Agriculture

The U.S. Department of Agriculture (USDA) obligated an estimated $2.4 billion for R&D in FY 2008, with the main focus on life sciences. The agency is also one of the largest research funders in the social sciences, particularly agricultural economics. Of USDA's total obligations for FY 2008, about 64% ($1.5 billion) funded intramural R&D, chiefly the Agricultural Research Service.

Department of Commerce

The Department of Commerce (DOC) obligated an estimated $1.1 billion for R&D in FY 2008, mainly for the R&D activities of the National Oceanic and Atmospheric Administration and NIST. Research accounted for 91% of the R&D for the department as a whole (10% for basic research and 81% for applied research); 78% of the total was for intramural R&D; and almost 22% supported extramural performers, primarily universities and colleges.

Other Agencies

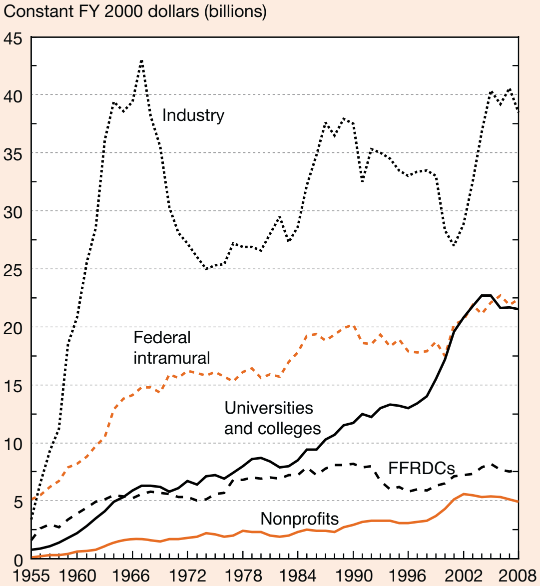
Of the other R&D-funding agencies, eight obligated between $100 million and $1 billion for R&D in FY 2008 (table 4-8). This group included the Departments of Transportation, Homeland Security, the Interior, Veterans Affairs, and Education; the Environmental Protection Agency; the Smithsonian Institution; and the Agency for International Development. These agencies also varied with respect to the character of the research and the roles of intramural, FFRDC, and extramural performers.

Federal Spending on R&D by Performer

Academia

The federal government has historically been the primary source of funding for R&D performed by universities and colleges. Federal obligations for academic R&D in FY

Figure 4-9
Federal obligations for R&D, by performing sector: FY 1955–2008



FFRDC = federally funded research and development center

NOTE: Data for FY 2008 are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007-09.

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2008 totaled an estimated $25.7 billion (current dollars). As figure 4-9 illustrates, federal funding for academic R&D generally has increased over the long term. In FY 1955, federal obligations for academic R&D stood at $0.8 billion in constant 2000 dollars and accounted for 7% of all federal R&D funding. In FY 1985, federal obligations to this sector were $9.4 billion, 13% of all federal R&D funding. The corresponding figures for FY 2008 were $21.5 billion and 23%, respectively.

Federal funding of academic R&D grew rapidly after FY 1998, the result of a successful bipartisan effort to double the budget of NIH from its FY 1998 level over the following 5 years. Since FY 2004, however, federal R&D obligations to universities and colleges have failed to keep pace with inflation. (For additional details on academic R&D, see chapter 5.)

Business

Federal obligations for R&D performed by businesses totaled an estimated $46.0 billion in FY 2008. For decades, the business sector has consistently received the bulk of federal R&D funds (figure 4-9).

Space program investments in the 1960s fueled the growth of federal obligations for business R&D, but after the successful Apollo 11 mission to the moon, R&D obligations to industry declined. A decade later, Cold War investments in military technology resulted in a renewed period of growth. Similarly, military investment in the aftermath of September 11, 2001, has increased the flow of federal R&D funding to industry. Adjusting for inflation, federal R&D obligations to industry increased by 42% from FY 2001 to 2008.

The amount of federally funded R&D reported by industry began to diverge from the amount reported by the federal government beginning in FY 1989. For details on this discrepancy, see the sidebar "Tracking R&D: The Gap Between Performer- and Source-Reported Expenditures."

Federal Intramural R&D

Federal obligations for federal intramural R&D totaled an estimated $26.8 billion in FY 2008. These funds supported R&D performed at federal agencies' intramural laboratories, as well as the costs associated with the planning and administration of both intramural and extramural R&D projects.

Among individual agencies, DOD funds the most intramural R&D, having accounted for 56% of all federal obligations for intramural R&D in FY 2008 (table 4-9). DOD's intramural R&D obligations are almost three times those of HHS, the second-largest performer of federal intramural R&D. Only two other agencies reported intramural R&D obligations of more than $1 billion in FY 2008: NASA and USDA.

FFRDCs

Unique organizations in the federal R&D system, FFRDCs were established to help the U.S. government meet special long-term research or development needs that could not be met as effectively by existing in-house or contractor resources. They were first established during World War II to assist DOD and DOE with R&D on nuclear weapons. Today, FFRDCs perform R&D for both defense and civilian applications across a broad range of S&E fields. Of the 37 currently active FFRDCs (appendix table 4-22), 16 are sponsored by DOE, the most of any federal agency. These 16 organizations accounted for about 69% of the R&D obligations of all FFRDCs combined in FY 2007.

Five FFRDCs reported R&D obligations of more than $600 million in FY 2007: Los Alamos National Laboratory (DOE), Jet Propulsion Laboratory (NASA), Lawrence Livermore National Laboratory (DOE), Sandia National Laboratory (DOE), and Oak Ridge National Laboratory (DOE). These five accounted for 55% of the FFRDC total that year. Los Alamos National Laboratory and Lawrence Livermore National Laboratory are the only two laboratories in the United States where research on the nation's nuclear stockpile is conducted.

Federal Spending on Research by Field

Federal agencies fund research (that is, basic research plus applied research, excluding development) in a wide range of S&E fields, from physics and mathematics to aeronautical engineering to sociology. Furthermore, the share of funding for research differs by field, as do the trends in funding over time.

Tracking R&D: The Gap Between Performer- and Source-Reported Expenditures

In some OECD countries, including the United States, figures for total government R&D support reported by government agencies differ from those reported by performers of R&D work. In keeping with international guidance and standards, most countries' national R&D expenditure totals and time series are based primarily on data reported by performers (OECD 2002). Differences may be expected between funder and performer series for many reasons, such as different bases used for reporting government obligations (fiscal year) and performance expenditures (calendar year). Nonetheless, the gap between the two U.S. R&D series has widened over the past decade or more.

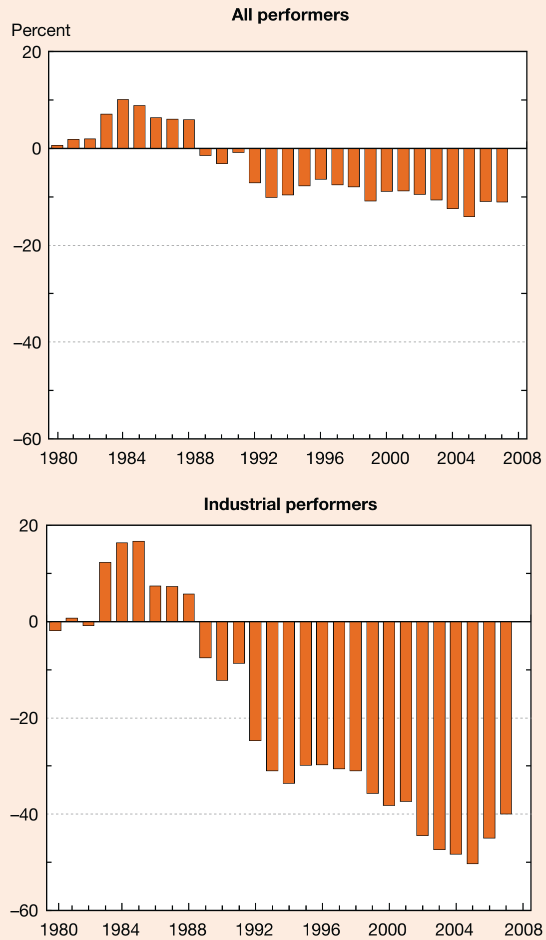
During the mid-1980s, performer-reported federal R&D in the United States exceeded federal reports of funding by $3 to $4 billion annually (5% to 10% of the government total). This pattern reversed itself toward the end of the decade; in 1989, the government-reported R&D total exceeded performer reports by $1 billion. For FY 2007, federal agencies reported obligating $114 billion in total R&D to all R&D performers ($44 billion to the business sector), compared with $101 billion in federal funding reported by the performers of R&D ($27 billion by businesses). In other words, the business-reported total was approximately 40% smaller than the federally reported R&D support to industry in FY 2007 (figure 4-C). The difference in federal R&D totals resided primarily in DOD funding of development activities by industry.

Several investigations into the possible causes for the data gap have produced insights but no conclusive explanation. According to a General Accounting Office investigation (GAO 2001):

> Because the gap is the result of comparing two dissimilar types of financial data [federal obligations and performer expenditures], it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the federal R&D funds obligated to them. Thus, even if the data collection and reporting issues were addressed, a gap would still exist.

Echoing this assessment, the National Research Council (2005a) noted that comparing federal outlays for R&D (as opposed to obligations) to performer expenditures results in a smaller discrepancy. In FY 2007, federal agencies reported total R&D outlays of $109 billion.

Figure 4-C
Discrepancy in U.S. performer-reported and agency-reported federal R&D: 1980–2007



NOTE: Difference defined as percentage of federally reported R&D, with positive difference indicating that performer-reported R&D exceeds agency-reported R&D.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), National Patterns of R&D Resources (annual series); and NSF/SRS, Federal Funds for Research and Development: Fiscal Years 2007–09 (forthcoming). See appendix table 4-21.

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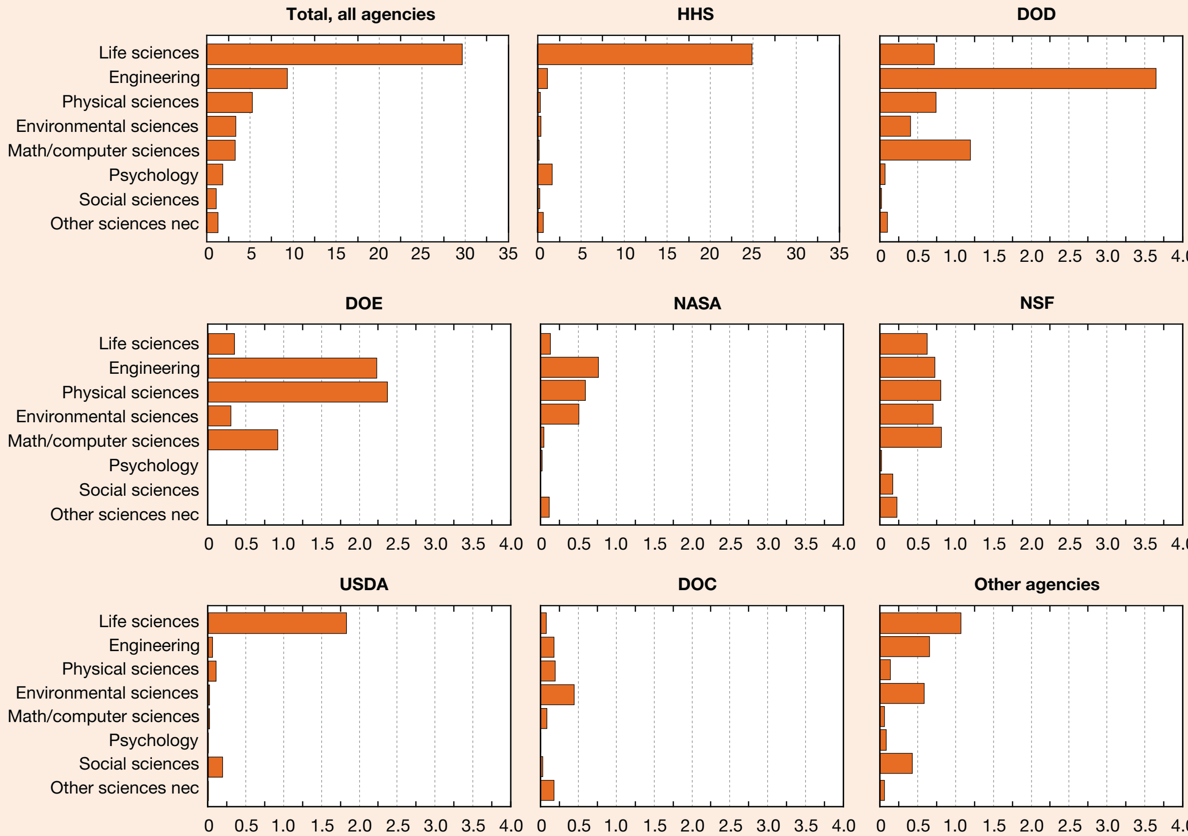
In FY 2008, an estimated $55.1 billion (48%) of the $114.6 billion for all R&D supported research. Of this total, $29.7 billion (54%) supported research in the life sciences (figure 4-10; appendix table 4-23). The fields with the next-largest amounts were engineering ($9.4 billion, 17%) and the physical sciences ($5.2 billion, 10%), followed by environmental sciences ($3.3 billion, 6%), and mathematics and computer sciences ($3.3 billion, 6%). The balance of

Figure 4-10
Federal obligations for research, by agency and major S&E field: FY 2008
(Billions of current dollars)



nec = not elsewhere classified; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

NOTES: Scale differs for total and HHS compared to the other agencies listed. Figures for FY 2008 are preliminary. Research includes basic and applied research.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–2009. See appendix table 4-23.

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federal obligations for research in FY 2008 supported the social sciences, psychology, and all other sciences ($4.2 billion overall, 8% of the total for research).

HHS, primarily through NIH, accounted for the largest share (54%) of federal obligations for research in FY 2008. Most of this amount funded research in medical and related life sciences. The five next-largest federal agencies for research funding that year were DOD (12%), DOE (11%), NSF (7%), USDA (4%), and NASA (4%).

DOD's research funding emphasized engineering ($3.7 billion), and mathematics and computer sciences ($1.2 billion). DOE provided substantial funding for research in the physical sciences ($2.4 billion) and engineering ($2.2 billion), whereas USDA's research funding was chiefly directed at the life sciences ($1.8 billion). NASA's research funding emphasized engineering ($0.8 billion), followed by the physical sciences ($0.6 billion) and environmental sciences ($0.5 billion). NSF, which has a mission to "promote the progress of science," had a relatively balanced research portfolio, contributing between $0.6 and $0.8 billion to researchers in each of the following fields: mathematics and computer sciences, physical sciences, engineering, environmental sciences, and life sciences.

From 1986 to 2008, real growth in federal obligations for research averaged 3.2% per year, increasing from $23.1 billion in 2000 dollars in FY 1986 to $45.0 billion in FY 2008 (appendix table 4-24). The fields that experienced higher-than-average growth during this period were mathematics and computer sciences (5.5% per year in real terms), life sciences (4.8%), and psychology (5.8%). Funding for the remaining fields also grew at a faster rate than inflation over this period: social sciences (1.9%), engineering (1.8%), and environmental sciences (1.3%).

Federal R&D Tax Credits

Background

Contributions of R&D to economic growth and social welfare, along with likely underinvestment by private performers, given the difficulty in fully appropriating R&D benefits, are often cited as reasons for justifying public support for R&D (NRC 2005b).[23] In addition to direct government funding discussed earlier in this chapter, fiscal policy tools used to provide such support include tax incentives.[24] The federal government offers several corporate tax incentives for qualified R&D expenditures including a deduction under Internal Revenue Code (IRC) section 174 (C.F.R. Title 26) and a tax credit under section 41. As of 2006, at least 32 states also offered credits for company-funded R&D (NSB 2008; Wilson forthcoming). This section focuses on business R&D tax credits at the federal level.

The research and experimentation (R&E) tax credit, established by the Economic Recovery Tax Act of 1981 (Public Law 97-34), covers R&D activities performed in the United States by domestic and foreign-owned firms but excludes R&D conducted abroad by U.S. companies. It is subject to periodic extensions and, at the time of writing, was last renewed by the Emergency Economic Stabilization Act of 2008[25] through 31 December 2009.

The R&E tax credit encompasses a regular credit, as well as credits for payments for basic research to qualified universities, scientific research organizations, or grant organizations, and for payments to energy research consortia. Under the regular credit, companies can take a 20% credit for qualified research above a base amount for activities undertaken in the United States (IRC section 41(a)(1)).[26] Thus, the regular credit is characterized as a fixed-base incremental credit. An incremental design is intended to encourage firms to spend more on R&D than they otherwise would by lowering after-tax costs. At the same time, the actual or effective credit rate for corporate taxpayers is lower than 20% because of limitations involving deductions under IRC section 174 (Guenther 2008).[27]

Federal Corporate Tax Credit Claims

According to the IRS Statistics of Income Division (SOI),[28] U.S. companies claimed an estimated $7.3 billion in federal R&E tax credits in 2006, involving close to 11,000 corporate tax returns, compared with $6.4 billion in 2005 (table 4-10).[29] The proportion of R&E credits going to corporations with business receipts of $250 million or more has fluctuated narrowly between 75% and 80% since 2003 and was 75% in 2006.[30]

For all industries, the size of R&E claims was about 3.3% relative to company-funded R&D in 2006, a proportion that has changed little in recent years (figure 4-11). Appendix tables 4-25 and 4-26 show data by NAICS industry up to 2005 (latest available year by detailed industry). Five industries accounted for about three-quarters of R&E credit claims in 2005. These industries had much higher ratios of R&E claims to industry-funded R&D: computer and electronic products (26%); chemicals, including pharmaceuticals and

Table 4-10
Federal research and experimentation tax credit claims and corporate tax returns claiming credit: 1990–2006

Year	Tax credit claims ($millions)	Tax returns
1990	1,547	8,699
1991	1,585	9,001
1992	1,515	7,750
1993	1,857	9,933
1994	2,423	9,150
1995	1,422	7,877
1996	2,134	9,709
1997	4,398	10,668
1998	5,208	9,849
1999	5,281	10,019
2000	7,079	10,495
2001	6,356	10,389
2002	5,656	10,254
2003	5,488	10,369
2004	5,554	10,244
2005	6,363	11,290
2006	7,311	10,788

SOURCE: Internal Revenue Service, Statistics of Income, special tabulations (historical data), http://www.irs.gov/taxstats/article/0,,id=164402,00.html (2006), accessed 19 June 2009.

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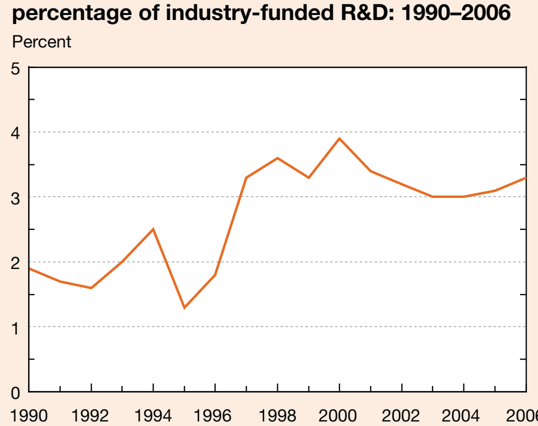
Figure 4-11
Research and experimentation credit claims as percentage of industry-funded R&D: 1990–2006



SOURCES: Internal Revenue Service, Statistics of Income, special tabulations; and National Science Foundation, Survey of Industrial Research and Development (annual series).

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Comparing International R&D Expenditures

Comparisons of international R&D statistics are hampered by the lack of R&D-specific exchange rates. If countries do not share a common currency, some conversion must be made to compare their R&D expenditures. Two approaches are commonly used to facilitate international R&D comparisons: (1) normalize national R&D expenditures by dividing by GDP, thereby obviating the need for currency conversion altogether or (2) convert all foreign-denominated expenditures to a single currency, resulting in indicators of absolute effort. The first method is a straightforward calculation but permits only gross national comparisons of R&D intensity. The second method permits absolute-level comparisons and analyses of countries' sector- and field-specific R&D, but it entails choosing an appropriate method of currency conversion.

Because no widely accepted R&D-specific exchange rates exist, the choice is between market exchange rates (MERs) and purchasing power parities (PPPs). These rates are the only series consistently compiled and available for a large number of countries over an extended period of time.

MERs. At their best, MERs represent the relative value of currencies for goods and services that are traded across borders. That is, MERs measure a currency's relative international buying power. Nevertheless, MERs may not accurately reflect the true cost of goods or services that are not traded internationally. In addition, fluctuations in MERs as a result of currency speculation, political events (such as wars or boycotts), and official currency intervention greatly impair their statistical utility—despite the fact that such occurrences have little or nothing to do with changes in the relative prices of internationally traded goods.

PPPs. PPPs were developed because of the shortcomings of MERs (Ward 1985). PPPs take into account the cost differences across countries of buying a similar market basket of goods and services in numerous expenditure categories, including nontradables. The PPP basket is thereby assumed to be representative of total GDP across countries.

Although the goods and services included in the market basket used to calculate PPP rates differ from the major components of R&D costs (fixed assets, as well as wages of scientists, engineers, and support personnel), they still result in a more suitable domestic price converter than one based on foreign trade flows. Exchange-rate movements bear little relationship to changes in the cost of domestically performed R&D. The adoption of the euro as the common currency for many European countries provides a useful example: although Germany and Portugal now share a common currency, the real costs of most goods and services are substantially less in Portugal. PPPs are, therefore, the preferred international standard for calculating cross-country R&D comparisons wherever possible and are used in all official R&D tabulations of the OECD.*

Because MERs tend to understate the domestic purchasing power of developing countries' currencies, PPPs can produce substantially larger R&D estimates than MERs for these countries. For example, China's 2006 R&D expenditures (as reported to the OECD) are $38 billion using MERs but $87 billion using PPPs. (Appendix table 4-2 lists the relative difference between MERs and PPPs for a number of countries.)

Although PPPs are available for developing countries, such as India and China, they may be less useful for converting R&D expenditures in such countries than in more developed countries for a number of reasons:

- It is difficult or impossible to assess the quality of PPPs for some countries, most notably China. Although PPP estimates for OECD countries are quite reliable, PPP estimates for developing countries are often rough approximations. The latter estimates are based on extrapolations of numbers published by the United Nations International Comparison Program and by Professors Robert Summers and Alan Heston of the University of Pennsylvania and their colleagues.
- The composition of the market basket used to calculate PPPs likely differs substantially between developing and developed countries. The structural differences in the economies of developing and developed countries, as well as disparities in income, may result in a market basket of goods and services in a developing country that is quite different from that of a developed country, particularly as far as these baskets relate to the various costs of R&D.
- R&D performance in developing countries often is concentrated geographically in the most advanced cities and regions in terms of infrastructure and level of educated workforce. The costs of goods and services in these areas can be substantially greater than for the country as a whole.

*Recent research raises some questions about the use of GDP PPPs for deflating R&D expenditures. In analyzing the manufacturing R&D inputs and outputs of six industrialized OECD countries, Dougherty et al. (2007) conclude that "the use of an R&D PPP will yield comparative costs and R&D intensities that vary substantially from the current practice of using GDP PPPs, likely increasing the real R&D performance of the comparison countries relative to the United States."

medicines (18%); transportation equipment, including motor vehicles and aerospace (13%); information, including software (10%); and professional, scientific, and technical services, including computer and R&D services (10%). The same five industries accounted for 80% of 2005 company-funded R&D from the NSF/Census Survey of Industrial Research and Development.[31]

International R&D Comparisons

Data on R&D expenditures can provide a broad picture of the changing distribution of R&D activities around the world. R&D data available from the OECD cover the organization's 30 member countries and 9 nonmembers. Data from the United Nations Educational, Scientific, and Cultural Organization's (UNESCO's) Institute for Statistics are used here to supplement OECD statistics in order to cover a larger set of countries. Increasingly, these data are collected following OECD standards, but the reader should treat them as broad indicators of trends and patterns rather than as precise measures.

International comparisons involve currency conversions. The discussion here follows the international convention to convert foreign currencies into U.S. dollars via purchasing power parity (PPP) exchange rates. (See sidebar "Comparing International R&D Expenditures.")

Global Patterns of R&D Expenditures

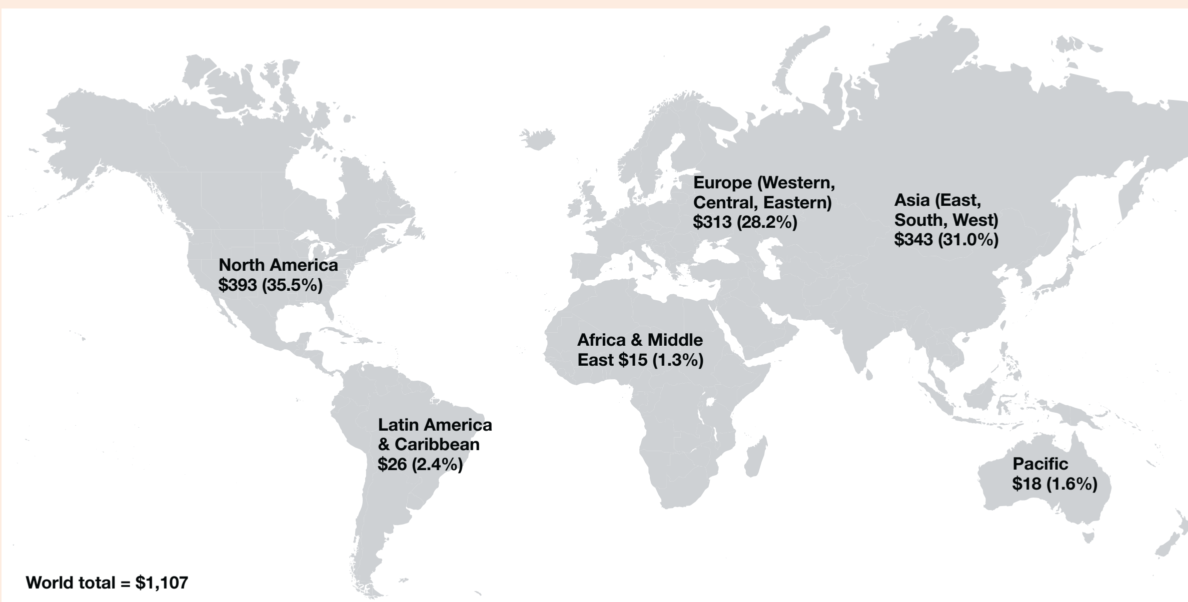
Worldwide R&D expenditures in 2007 totaled an estimated $1,107 billion. Although many countries conduct R&D, much of global R&D performance continues to be concentrated in a few high-income countries and regions.

Three regions predominate (figure 4-12). North America accounts for 35% ($393 billion) of worldwide R&D performance; Asia, 31% ($343 billion); and Europe, 28% ($313 billion). The small remainder, approximately 5%, reflects the R&D of countries in the Latin America/Caribbean, Pacific, and Africa/Middle East regions.

The concentration is more apparent when reviewing the data of specific countries (table 4-11). By itself, the United States accounts for about 33% of the current global R&D total. Japan, the second-largest performer, accounts for about 13%. China (9%) comes next, followed by Germany (6%) and France (4%).

The top two countries thus account for 47% of the global R&D total, whereas the top five countries represent about 66%. Adding the next 5 countries—South Korea,

Figure 4-12
National R&D expenditures and share of world total, by region: 2007
(Billions of U.S. PPP dollars)



PPP = purchasing power parity

NOTES: Foreign currencies converted to dollars through purchasing power parities. Sources track R&D for 126 countries. Some country figures are estimated.

SOURCES: United Nations Educational, Scientific and Cultural Organization (UNESCO), Institute for Statistics, http://www.uis.unesco.org, accessed October 2009; and Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

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Table 4-11
International comparisons of gross domestic expenditures on R&D and R&D share of gross domestic product, by country/economy/region: Most recent year

Country/economy	GERD (millions PPP$)	GERD/ GDP (%)	Country/economy	GERD (millions PPP$)	GERD/ GDP (%)
Regions/selected countries:			Central and Eastern Europe		
North America			Russian Federation (2007)	23,482.0	1.12
United States (2007)	368,799.0	2.68	Turkey (2007)	6,830.0	0.71
Canada (2008)	23,781.0	1.82	Czech Republic (2007)	3,813.8	1.54
			Poland (2007)	3,482.3	0.57
Latin America and Caribbean			Hungary (2007)	1,822.9	0.97
Mexico (2005)	5,919.0	0.46	Romania (2007)	1,433.9	0.53
Argentina (2007)	2,656.2	0.51	Slovenia (2007)	828.3	1.53
			Slovak Republic (2007)	497.9	0.46
Western Europe					
Germany (2007)	71,860.8	2.54	East, South, West Asia		
France (2007)	43,232.6	2.08	Japan (2007)	147,800.8	3.44
United Kingdom (2007)	38,892.8	1.79	China (2007)	102,331.0	1.49
Italy (2006)	19,678.1	1.13	South Korea (2007)	41,741.6	3.47
Spain (2007)	18,000.3	1.27	Taiwan (2007)	18,324.8	2.63
Sweden (2007)	12,076.3	3.60	Singapore (2007)	5,945.5	2.61
Netherlands (2007)	10,949.8	1.70			
Austria (2008)	8,530.1	2.66	Pacific		
Switzerland (2004)	7,474.3	2.90	Australia (2006)	14,914.4	2.01
Belgium (2007)	7,028.3	1.87	New Zealand (2007)	1,383.7	1.20
Finland (2008)	6,519.7	3.46			
Denmark (2007)	5,008.4	2.55	Africa and Middle East		
Norway (2007)	4,133.0	1.64	Israel (2007)	8,845.8	4.68
Ireland (2008)	2,855.1	1.45	South Africa (2005)	3,654.3	0.92
Portugal (2007)	2,849.7	1.18			
Greece (2007)	1,828.4	0.58	Selected country groups:		
Luxembourg (2007)	624.0	1.63	OECD (2007)	886,347.1	2.29
Iceland (2008)	318.2	2.76	European Union-27 (2007)	262,985.0	1.77
			G-7 countries (2007)	715,329.6	2.53

EU = European Union; GDP = gross domestic product; GERD = gross domestic expenditure on R&D; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTE: Data for Israel is civilian R&D only.

SOURCE: OECD, Main Science and Technology Indicators (2009/1).

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the United Kingdom, the Russian Federation, Canada, and Italy—increases the total to just below 80%, meaning that four-fifths of the world's R&D is concentrated in just 10 countries.

With respect to major geopolitical groupings, the R&D performance of the 27 nations of the European Union (EU-27) currently accounts for about 24% of the global total. The Group of Seven (G-7) industrialized countries, of which the United States is a member (along with Canada, France, Germany, Italy, Japan, and the United Kingdom), account for about 65%. The 30 countries constituting the OECD account for about 80% of worldwide R&D. (Among the current major R&D-performing nations, only China is not an OECD member.)

U.S. dominance of global R&D performance is notable as well with respect to these country groupings. U.S. R&D expenditures are currently 40% greater than the total for all of the EU-27 countries together. Within the G-7, the United States currently accounts for more than half (52%) of the R&D total. (The U.S. share was 48% in 1990. It has exceeded 50% since 1997.) Within the OECD, U.S. R&D is about 42% of the total.

According to OECD statistics (figure 4-13), total R&D by the EU-27 nations has been growing in real dollars over the past 10 years at an average annual rate of 3.3%. The pace of real growth during the same period for Germany, France, and the United Kingdom has been slower: averaging 2.9%, 1.8%, and 3.0%, respectively. By comparison, the U.S. pace of growth, on the same basis, has averaged 3.3%. Growth in Japan has been slower, at an annual average rate of 3.0%. For the OECD as a whole, real growth in R&D expenditures has also expanded on average at a rate of 3.6% annually over the past 10 years.

China continues to show the most dramatic growth pattern. The World Bank revised China's PPP exchange rate in late 2007, significantly lowering the dollar value of its R&D

expenditures. Nonetheless, the pace of real annual growth over the past 10 years in China remains exceptionally high at just above 19%.

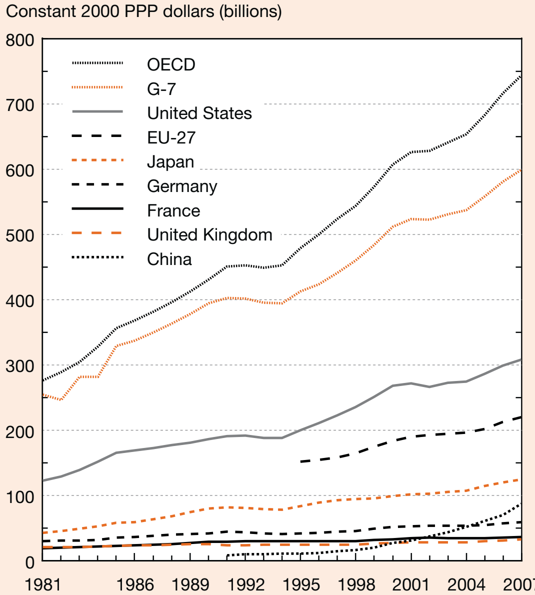
Finally, both India and Brazil are among the world's larger R&D performers, although neither has yet become part of OECD's statistical system. According to the UNESCO statistics, India performed $15 billion of R&D in 2004 (current U.S. dollars, PPP) and Brazil performed $13 billion in 2005. Both figures are about double the levels of R&D performance that each country reported in the mid-1990s. These levels of R&D expenditures would put both India and Brazil in the world's top 15 R&D performers.

Comparison of Country R&D Intensities

R&D intensity—typically measured as the ratio of a country's national R&D expenditures to GDP for a given year—provides another basis for international comparisons of R&D performance. This approach does not require conversion of a country's currency to a standard international benchmark yet still provides a way to adjust for differences in the sizes of national economies.

Figure 4-13
Gross domestic expenditures on R&D by United States, EU-27, OECD, and selected other countries: 1981–2007

Constant 2000 PPP dollars (billions)



EU = European Union; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTES: Data not available for all countries for all years. U.S. data reflect OECD methodology for calculating gross expenditures on R&D. Japan data for 1996 onward may not be comparable with earlier years because of changes in methodology.

SOURCE: OECD, Main Science and Technology Indicators (2009/1). See appendix table 4-27.

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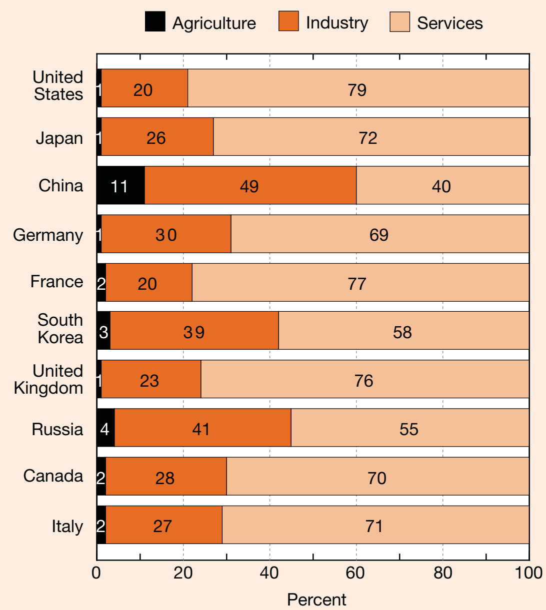
The structure of a national economy—that is, the relative prominence of agriculture, manufacturing, services, and so on—influences the interpretation of R&D intensity statistics. Businesses and organizations differ widely in their relative need for investment in the latest science and technology, and countries whose overall GDP depends considerably on industries in the high-technology sector will exhibit higher R&D/GDP ratios than other countries.

Figure 4-14 provides background information on the GDP composition of the current top 10 R&D-performing countries. Agriculture is a comparatively small component (4% or less) for 9 of these 10 countries; only China is an exception, where agriculture is currently about 11%. For all but four of the countries, services account for 70% or more of current GDP. In China (49%), South Korea (39%), and Russia (41%), industry accounts for a more sizable fraction of GDP.

Total R&D/GDP Ratios

The U.S. R&D/GDP ratio was about 2.7% in 2007 (table 4-11). At this level, the United States is eighth among the economies tracked by the OECD. Israel has the highest ratio at 4.7%, with Sweden, Finland, Japan, and South Korea all above 3%.

Figure 4-14
Composition of gross domestic product for selected countries, by sector: 2008



NOTES: Data for Russia are 2007. Data cover the 10 largest R&D performing countries.

SOURCE: Central Intelligence Agency, *The World Factbook*, http://www.cia.gov/library/publications/the-world-factbook/index.html, accessed 25 February 2009.

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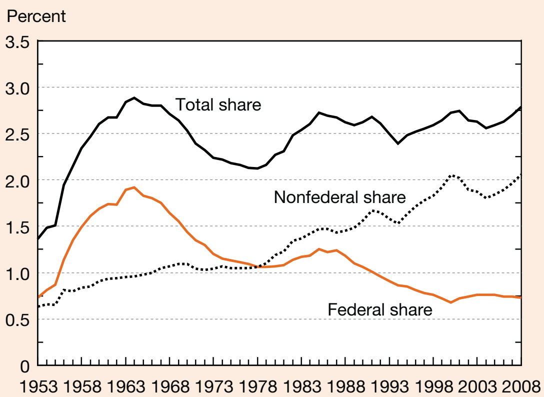
The R&D/GDP ratio in the United States has ranged from 1.4% in 1953 to a high of 2.9% in 1964 and has fluctuated in the range of 2.6% to 2.7% in recent years (figure 4-15). Most of the growth over time in the U.S. R&D/GDP ratio can be attributed to increases in nonfederal R&D spending, financed primarily by business. Non-federally financed R&D increased from about 0.6% of GDP in 1953 to 2.0% of GDP in 2007. This increase in the nonfederal R&D/GDP ratio reflects the growing role of business R&D in the national R&D system and, more broadly, the growing prominence of R&D-derived products and services in the national and global economies.

Historically, the many peaks and valleys in the U.S. R&D/GDP ratio reflect changing federal R&D priorities. The ratio's drop from its peak in 1964 largely resulted from federal cutbacks in defense and space R&D programs; from 1975 to 1979, gains in energy R&D activities kept the ratio stable. Beginning in the late 1980s, cuts in defense-related R&D kept growth in federal R&D spending below GDP growth, while nonfederal growth kept pace with or exceeded that of GDP. Since 2000, defense-related R&D spending has helped federal R&D spending growth outpace the growth of GDP.

Among other top 10 R&D-performing countries, total R&D/GDP ratios over the past 10 years show mixed trends (figure 4-16). Compared with 1996 R&D/GDP ratios, 2007 (or 2006) ratios were substantially higher in Japan, China, and South Korea; modestly higher for Germany and Canada; somewhat higher for Italy and the United Kingdom; and lower for France. Russia's R&D/GDP ratio grew consistently from the late 1990s but has fallen back to only somewhat above its 1996 level in recent years.

Figure 4-15
U.S. R&D share of gross domestic product: 1953–2008



NOTE: Data for 2008 are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series).

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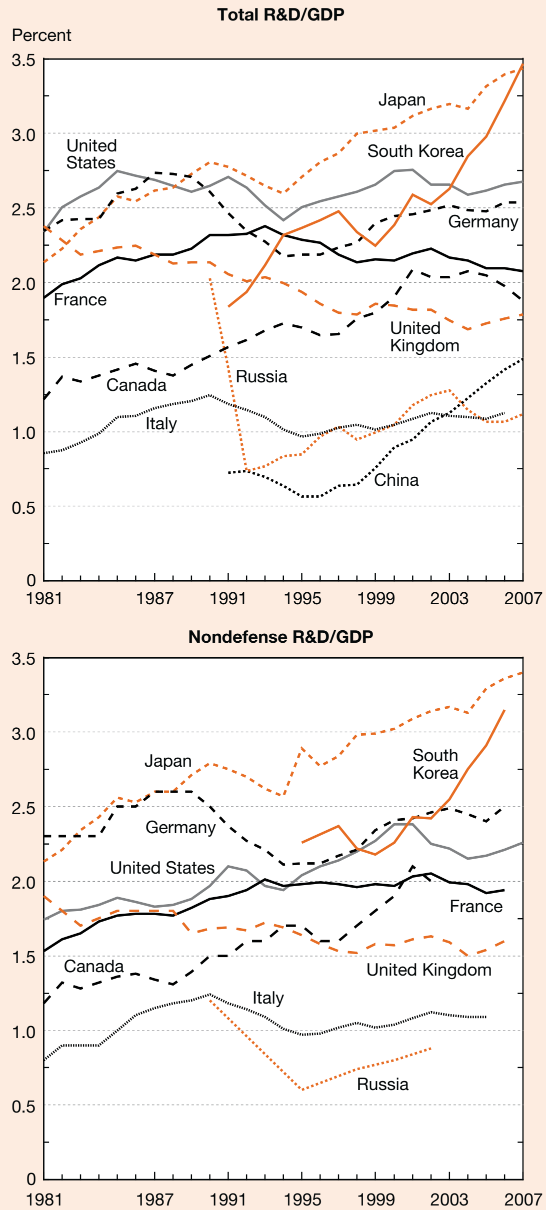
Figure 4-16
Gross expenditures on R&D as share of gross domestic product, for selected countries: 1981–2007



GDP = gross domestic product; OECD = Organisation for Economic Co-operation and Development

NOTES: Top 10 R&D performing countries. Data not available for all countries for all years. U.S. data reflect OECD methodology for calculating gross expenditures on R&D. Japan data for 1996 onward may not be comparable with earlier years because of changes in methodology.

SOURCE: OECD, Main Science and Technology Indicators (2009/1). See appendix tables 4-27 and 4-28.

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In addition to the United States, countries in Nordic and Western Europe and the most advanced areas of Asia have R&D/GDP ratios above 1.5%. This pattern broadly reflects the global distribution of wealth and level of economic development. Countries with high incomes tend to emphasize the production of high-technology goods and services and are also those that invest heavily in R&D activities. Private sectors in low-income countries often have a low concentration of high-technology industries, resulting in low overall R&D spending and, therefore, low R&D/GDP ratios.

Nondefense R&D and Basic Research

Further perspective is provided by the ratio of nondefense R&D expenditures to GDP. This ratio more directly measures civilian R&D intensity and is useful when comparing nations with substantially different financial commitments to national defense. Figure 4-16 shows the trends since the early 1980s in the nondefense R&D/GDP ratios for 7 of the top 10 R&D-performing nations (for which data are available). Although the U.S. ratio (2.3% in 2007) ranks ahead of that for the United Kingdom, it lags behind Japan, South Korea, and Germany.

Another perspective comes from the extent to which spending on basic research accounts for a country's total R&D/GDP ratio. Estimates of the relative volume of basic research spending can provide a glimpse of the extent to which R&D resources are directed toward advancing the scientific knowledge base.

Based on the most recent data available, the U.S. basic research/R&D ratio is about 0.5% and accounts for less than a fifth of the total R&D/GDP ratio (table 4-12). France's basic research ratio is slightly above the U.S. figure but accounts for nearly a quarter of its total ratio. South Korea's basic research ratio is close to the U.S. and French figures but accounts for less of the total ratio. The basic research ratios for Japan, Italy, and especially China are below the U.S. figure.

The following countries have basic research-to-GDP ratios at or above the U.S. level: Switzerland (0.83%), Israel (0.78%), Singapore (0.48%), Australia (0.45%), and Denmark (0.44%).

R&D by Performing Sector and Source of Funds

In all top 10 countries ranked by R&D expenditures, the business sector is currently the largest performer, ranging from 77% for South Korea and Japan to 49% for Italy (table 4-13). Countries with relatively lower business-sector R&D

Table 4-12
Gross expenditures on R&D as share of gross domestic product, for selected countries: Most recent year
(Percent)

Country	All R&D/GDP	Nondefense R&D/GDP	Share	Basic R&D/GDP	Share
United States (2007)	2.68	2.26	84	0.47	18
Japan (2007)	3.44	3.40	99	0.40	12
China (2007)	1.49	NA	NA	0.05	3
Germany (2006)	2.54	2.50	98	NA	NA
France (2006)	2.10	1.94	92	0.50	24
South Korea (2006)	3.22	3.15	98	0.49	15
United Kingdom (2006)	1.76	1.60	91	NA	NA
Russian Federation (2002)	1.25	0.88	70	0.17	14
Canada (2008)	1.82	NA	NA	NA	NA
Italy(2005)	1.09	1.09	100	0.30	28
Taiwan (2007)	2.63	2.60	99	0.26	10
Spain (2003)	1.05	1.02	97	0.20	19
Australia (2006)	2.01	1.93	96	0.45	22
Sweden (2006)	3.74	3.50	94	NA	NA
Israel (2007)	NA	4.68	NA	0.78	NA
Switzerland (2004)	2.90	2.88	99	0.83	29
Finland (2007)	3.48	3.48	100	NA	NA
Denmark (2005)	2.54	NA	NA	0.44	17
Singapore (2007)	2.61	NA	NA	0.45	17
Ireland (2006)	1.30	1.30	100	0.31	24

NA = not available

GDP = gross domestic product

NOTES: Top 10 R&D performing countries (United States to Italy) and selected other countries. Figures for Israel are civilian R&D only.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

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tend to have greater higher education R&D; these countries include Canada, Italy, the United Kingdom, and France. The government sector is particularly prominent in the Russian Federation, Italy, China, and France.

China's business R&D sector has spurred much recent growth in national R&D expenditures, which rose from 60% of the total in 2000 to 72% in 2007. This increase reflects activities by private domestic companies and by multinational companies as well as the conversion of government-owned enterprises to the private sector.

With respect to R&D funding, the business sector supplies 66% of total R&D funds in the United States (table 4-14). In Japan and South Korea, the business sector supplies higher fractions of the total R&D funding than in the United States. Germany's and China's business sectors provide funding shares broadly similar to that of the United States. In France, Canada, the United Kingdom, Italy, and the Russian Federation, the business sector provides smaller shares of total R&D funding, but the government shares are relatively high. Government support for R&D is particularly low in Japan.

More precise analysis is impeded by the lack of comparable data for foreign-funded R&D in the United States (figure 4-17). Russia, the United Kingdom, and Canada had the strongest growth in foreign R&D funds during the 1990s but have recently experienced sharp drops. Foreign R&D funding largely comes from foreign companies but also includes resources from foreign governments and other overseas organizations. For European countries, growth

Table 4-13
Gross expenditures on R&D by performing sector, for selected countries: Most recent year
(Percent)

Country	Business	Government	Higher education	Private nonprofit
United States (2007)	71.9	10.7	13.3	4.2
Japan (2007)	77.9	7.8	12.6	1.7
China (2007)	72.3	19.2	8.5	0.0
Germany (2007)	69.9	13.9	16.2	0.0
France (2007)	63.2	16.5	19.2	1.1
South Korea (2007)	76.2	11.7	10.7	1.4
United Kingdom (2007)	64.1	9.2	24.5	2.1
Russian Federation (2007)	64.2	29.1	6.3	0.3
Canada (2008)	56.1	9.6	33.8	0.5
Italy (2006)	48.8	17.2	30.3	3.7

NOTE: Top 10 R&D performing countries.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

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Table 4-14
Gross expenditures on R&D by funding source, for selected countries: Most recent year
(Percent)

Country	Business	Government	Other domestic	Abroad
United States (2007)	66.4	27.7	5.8	NA
Japan (2007)	77.7	15.6	6.3	0.3
China (2007)	70.4	24.6	NA	1.3
Germany (2006)	68.1	27.8	0.4	3.8
France (2006)	52.4	38.4	2.2	7.0
South Korea (2007)	73.7	24.8	1.3	0.2
United Kingdom (2007)	47.2	29.3	5.8	17.7
Russian Federation (2007)	29.4	62.6	0.7	7.2
Canada (2008)	49.5	31.3	10.3	9.0
Italy (2006)	40.4	48.3	3.0	8.3

NA = not available

NOTES: Top 10 R&D performing countries. U.S. data on R&D funding from abroad not separately identified but included in sector totals.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

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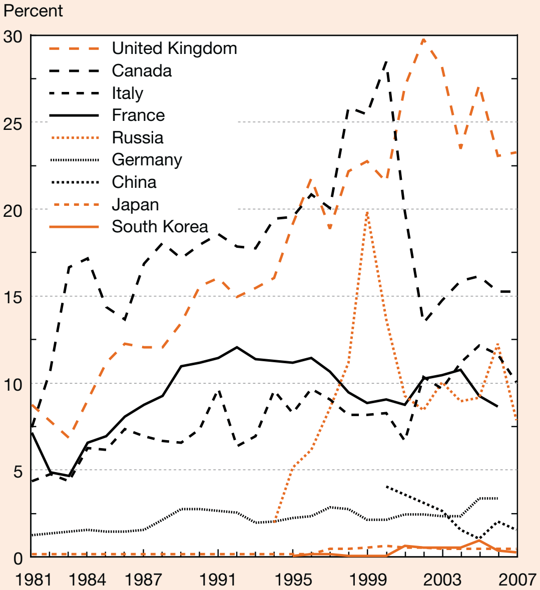
Figure 4-17
Business R&D financed by foreign sources, for selected countries: 1981–2007



NOTES: Top 10 R&D performing countries. Data not available for all countries for all years. Similar U.S. data not separately reported.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

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in foreign-funded R&D may reflect coordinated European Community (EC) efforts to foster cooperative shared-cost research through its European Framework Programmes.

Businesses in the United States also receive R&D funding from abroad. However, this funding is not separately reported in U.S. R&D statistics; instead, it is included in the figures reported for the business sector.[32]

Business Sector

The structure of business R&D varies substantially among countries in terms of both sector concentration and sources of funding. Because businesses account for the largest share of total R&D performance in the United States and most OECD countries, differences in business structure can help explain international differences in more aggregated statistics such as R&D/GDP. For example, countries with higher concentrations of R&D-intensive industries (such as pharmaceuticals or automotive manufacturing) are likely to also have higher R&D/GDP ratios than countries whose business structures are weighted more heavily toward less R&D-intensive industries.

Sector Focus for the United States and OECD Countries

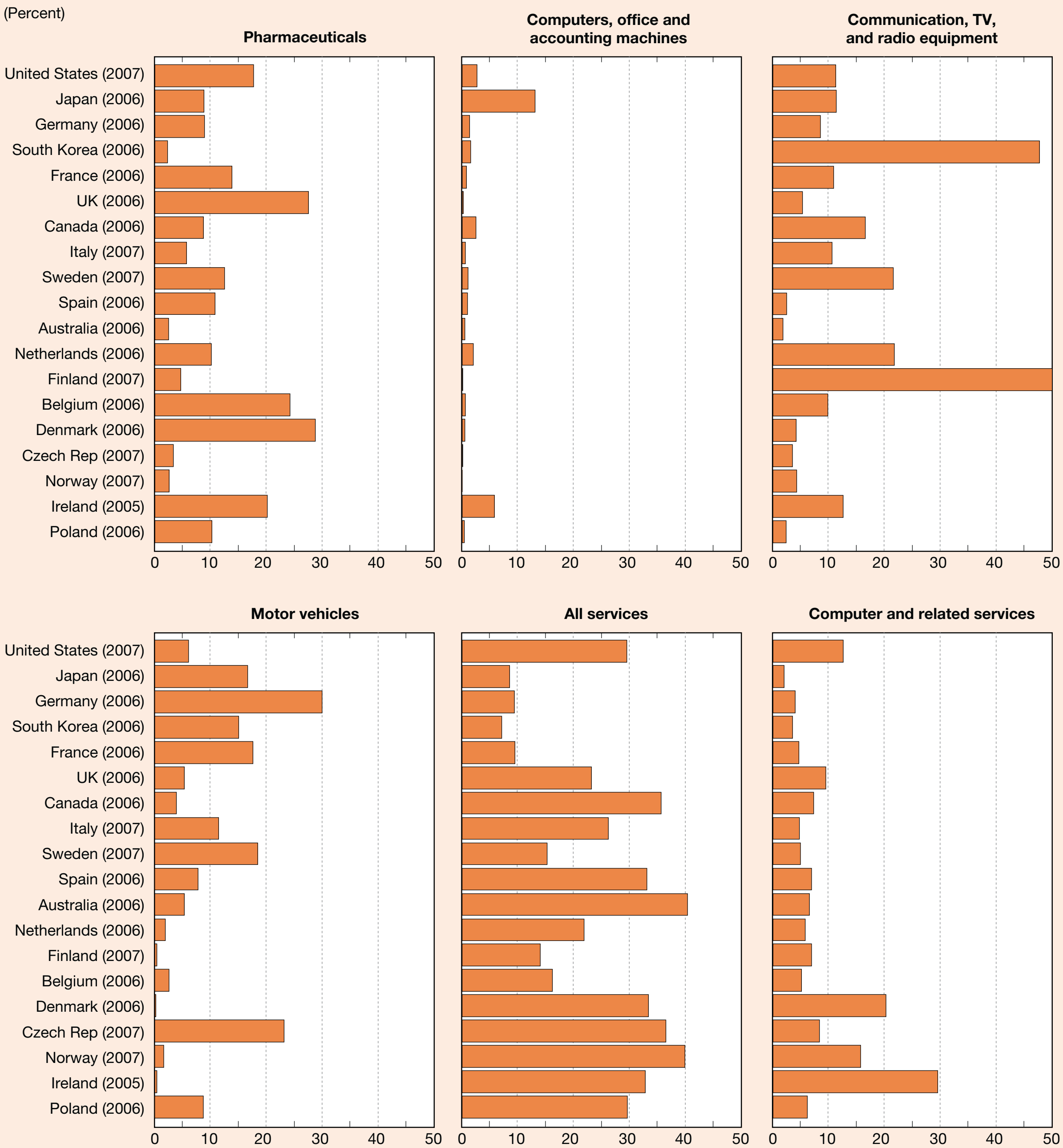
Using internationally comparable data, no one industry accounted for more than 18% of total business R&D in the United States in 2007 (figure 4-18; appendix table 4-31) (OECD 2009c). This circumstance stems largely from the fact that total business R&D expenditures are so large in the United States that it is difficult for any one sector to dominate. However, the diversity of R&D investment by industry in the United States is also an indicator of how the nation's accumulated stock of knowledge and well-developed S&T infrastructure have made it a popular location for R&D performance for a broad range of industries.[33]

Compared with the United States, many of the other countries shown in figure 4-18 display much higher industry sector concentrations. In countries with less business R&D, high sector concentrations can result from the activities of one or two large companies. This pattern is notable in Finland, where the communication, television, and radio equipment industry accounted for more than half of business R&D in 2007. This high concentration most likely reflects the activities of one company, Nokia, a major manufacturer of mobile phones at the forefront of the convergence of communications and the Internet. In contrast, South Korea's high concentration of R&D (48% of all business R&D in 2006) in this industry is not the result of any one or two companies, but reflects the structure of its export-oriented economy. South Korea is one of the world's top producers of electronic goods, and among its top export commodities are semiconductors, cellular phones, and computers. In the United States, the communication, television, and radio equipment industry accounted for 11% of all business R&D in 2007.

Other industries also exhibit relatively high concentrations of R&D by country. Automotive manufacturers ranked among the largest R&D-performing companies in the world in 2006. (See table 4-15 and sidebar "Global R&D Expenses of Public Corporations.") Hence, countries that are home to the world's major automakers also boast the highest concentration of R&D in the automotive manufacturing industry. This industry accounts for 30% of Germany's business R&D, 23% of the Czech Republic's, and 19% of Sweden's (figure 4-18), reflecting the operations of automakers such as Daimler AG and Volkswagen in Germany, Skoda in the Czech Republic, and Volvo and Saab in Sweden. Also home to large R&D-performing firms in this industry are France (18% of all business R&D; PSA Peugeot Citroën, Renault), Japan (17%; Toyota, Honda, Nissan), South Korea (15%; Hyundai, Kia), and Italy (12%; Fiat). In the United States, the automotive manufacturing industry accounted for 6% of all business R&D in 2007.

The pharmaceuticals industry is less geographically concentrated than the automotive manufacturing industry but is still prominent in several countries. The pharmaceuticals industry accounts for more than 27% of business R&D in Denmark and the United Kingdom, and more than 20% in

Figure 4-18
Share of industrial R&D, by industry sector and selected country: 2005–2007



UK = United Kingdom

NOTES: Countries listed in descending order by amount of total industrial R&D. Data are for years in parentheses.

SOURCES: Organisation for Economic Co-operation and Development, ANBERD database (2009), http://www.oecd.org/document/17/0,3343,en_2649_34445_1822033_1_1_1_1,00.html, accessed 15 June 2009; and National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (2007).

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Table 4-15
Global R&D spending by top 25 corporations: 2006

	R&D rank		R&D expense ($millions)			Sales ($millions)			R&D/sales ratio (%)	
Company (country)	2006	2005	2006	2005	Change (%)	2006	2005	Change (%)	2006	2005
Toyota Motor (Japan)	1	4	7,486	6,829	9.6	201,254	176,789	13.8	3.7	3.9
Pfizer (United States)	2	2	7,423	7,442	–0.3	48,201	51,298	–6.0	15.4	14.5
Ford Motor (United States)	3	1	7,200	8,000	–10.0	160,123	176,896	–9.5	4.5	4.5
Johnson & Johnson (United States)	4	8	7,125	6,312	12.9	53,194	50,434	5.5	13.4	12.5
Microsoft (United States)	5	7	7,121	6,584	8.2	51,122	44,282	15.4	13.9	14.9
DaimlerChrysler (Germany)	6	3	7,007	7,425	–5.6	199,246	196,863	1.2	3.5	3.8
GlaxoSmithKline (United Kingdom)	7	9	6,611	6,108	8.2	45,263	42,213	7.2	14.6	14.5
Siemens (Germany)	8	5	6,604	6,776	–2.5	114,779	99,164	15.7	5.8	6.8
General Motors (United States)	9	6	6,600	6,700	–1.5	207,349	190,215	9.0	3.2	3.5
Volkswagen (Germany)	10	12	6,030	5,364	12.4	137,846	125,219	10.1	4.4	4.3
Samsung Electronics (South Korea)	11	10	5,943	5,765	3.1	91,038	85,927	5.9	6.5	6.7
Intel (United States)	12	14	5,873	5,145	14.1	35,382	38,826	–8.9	16.6	13.3
Sanofi-Aventis (France)	13	13	5,823	5,315	9.6	37,293	35,897	3.9	15.6	14.8
International Business Machines (United States)	14	11	5,682	5,378	5.7	91,424	91,134	0.3	6.2	5.9
Roche Holding (Switzerland)	15	17	5,359	4,640	15.5	34,192	28,882	18.4	15.7	16.1
Novartis (Switzerland)	16	18	5,349	4,514	18.5	36,031	32,212	11.9	14.8	14.0
Nokia (Finland)	17	15	5,122	5,008	2.3	54,049	44,940	20.3	9.5	11.1
Matsushita Electric (Japan)	18	16	4,858	4,746	2.4	76,543	74,746	2.4	6.3	6.3
Honda Motor (Japan)	19	20	4,638	4,289	8.1	93,174	83,264	11.9	5.0	5.2
Sony (Japan)	20	19	4,571	4,469	2.3	69,715	62,822	11.0	6.6	7.1
Robert Bosch GmbH (Germany)	21	21	4,401	4,039	9.0	57,418	54,496	5.4	7.7	7.4
Motorola (United States)	22	24	4,106	3,680	11.6	42,879	36,843	16.4	9.6	10.0
Cisco Systems (United States)	23	30	4,067	3,322	22.4	28,484	24,801	14.9	14.3	13.4
Merck (United States)	24	22	4,020	3,848	4.5	22,636	22,012	2.8	17.8	17.5
Telefonaktiebolaget LM Ericsson (Sweden)	25	25	3,990	3,494	14.2	25,403	21,693	17.1	15.7	16.1

SOURCE: Institute of Electrical and Electronics Engineers (IEEE), IEEE Spectrum Top 100 R&D Spenders, Standard & Poor's data (2006), http://www.spectrum.ieee.org/images/dec07/images/12.RDchart.pdf, accessed 5 May 2009.

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Global R&D Expenses of Public Corporations

Most firms that make significant investments in R&D track their R&D expenses separately in their accounting records and financial statements. The annual reports of public corporations often include data on these R&D expenses. According to information gleaned from public reports, the 25 public corporations with the largest reported worldwide R&D expenses spent $143 billion on R&D in 2006. The six companies with the largest reported R&D expenses—Toyota, Pfizer, Ford Motor Company, Johnson & Johnson, Microsoft, and DaimlerChrysler—each spent between $7 billion and $7.5 billion. The six automobile manufacturers on the list reported combined spending of $39 billion on R&D (27.3% of the total for the top 25) (table 4-15). Eleven companies in the information and communications technologies (ICT) sector spent a total of $57.9 billion (40.5% of the total). The remaining eight companies include six pharmaceutical manufacturers and two diversified consumer product–oriented manufacturers. The top 25 companies are headquartered in 9 countries, with 10 headquartered in the United States. The location of a company's headquarters, however, is not necessarily the location of all its R&D activities. Most of the companies on this list have manufacturing and research facilities in multiple countries. (For more information, see section "R&D by Multinational Companies.")

Overall, R&D spending for the top 25 public corporations increased 5.8% in 2006. (The top 25 list was the same for 2006 as it was for 2005 except for the addition of Cisco Systems, Inc., and the deletion of Nissan Motor Company.) Sales for the group as a whole increased 6.5%; sales increased 5.2% for the automobile and pharmaceutical manufacturers, 8.9% for the ICT companies in the group, and 5.4% for the consumer product manufacturers. R&D expenses increased for the manufacturers (pharmaceuticals, 8.5%; automobiles, 0.9%; and consumer products, 11.4%). The ICT companies, representing the sector that has historically had the highest R&D intensity, reported a 6.6% increase.

Belgium and Ireland. Denmark, the largest performer of pharmaceutical R&D in Europe, is home to Novo Nordisk, a world leader in the manufacture and marketing of diabetes-related drugs, and H. Lundbeck, a research-based company specializing in psychiatric and neurological pharmaceuticals. The United Kingdom is the second-largest performer of pharmaceutical R&D in Europe and is home to GlaxoSmithKline, which manufacturers medicines and vaccines for the World Health Organization's three priority diseases—HIV/AIDS, tuberculosis, and malaria. GlaxoSmithKline was the third-largest pharmaceuticals company in the world in terms of R&D expenditures in 2005 and 2006 (table 4-15). In the United States, the pharmaceuticals industry accounted for 18% of all business R&D in 2007. U.S.-headquartered pharmaceutical companies include Abbott Laboratories, Bristol-Myers Squibb, Eli Lilly, Johnson & Johnson, Merck, Pfizer, Schering-Plough, and Wyeth.

The computers, office and accounting machines industry represents only a small share of business R&D in most countries. Among the OECD countries shown in figure 4-18 and appendix table 4-31, only Japan reports a double-digit concentration of business R&D in this industry, 13% (2006). Japan is the home of Fujitsu, Hitachi, and NEC. In the United States, the computers, office and accounting machines industry accounted for 3% of all business R&D in 2007. The United States is home to Apple, Dell, Hewlett-Packard, Sun Microsystems and other companies in this industry.

A significant trend in both U.S. and international business R&D activity has been the growth of R&D in the service sector. According to national statistics for recent years, the service sector accounted for 30% or more of all business R&D in 9 of the 19 OECD countries shown in figure 4-18 and less than 10% in only 4 of the countries. In the United States, service industries accounted for 30% of all business R&D in 2007.

Other Countries

Internationally comparable data for seven non-OECD countries have recently been made available in OECD's Analytical Business Enterprise R&D (ANBERD) database (OECD 2009c). Percentage shares of total business R&D by industry for Chile, China, Israel, the Russian Federation, Singapore, South Africa, and Taiwan are detailed in appendix table 4-31.

Among these countries, the new data show that the communication, television, and radio equipment industry accounts for more than 40% of all business R&D in Singapore and Taiwan and more than 15% in Israel and China. Motor vehicle and pharmaceutical R&D account for smaller percentages of business R&D than in most of the OECD countries. Motor vehicle R&D accounts for 5% or more of business R&D in South Africa and China, and the two countries with the highest percentages of pharmaceutical R&D are Singapore (8%) and China (4%). R&D in the computer, office and accounting machines industry accounts for 15% of the business R&D performed in Taiwan, the highest percentage among the seven nations.

Among the OECD countries shown in figure 4-18, the service sector accounts for as little as 7% of business R&D in South Korea to as much as 41% in Australia. The newly available data show a similar range among the seven nations. The percentage of business R&D accounted for by the service sector ranges from 7% in China to more than 60% in Israel and the Russian Federation.

Academic Sector

The academic sector's share of R&D is largest in Canada, where it accounted for 36% of national R&D performance in 2007 (table 4-13). It is lowest in the Russian Federation at 6%. The academic share in the United States and Japan is in the middle at 13%, whereas China is 9%.

Source of Funds

For most countries, the government is (and has long been) the largest source of academic research funding. (See sidebar "Government Funding Mechanisms for Academic Research.") Business support for academic R&D has increased over the past 25 years among the OECD countries as a whole. It was around 3% in the early 1980s, nearly 6% in 1990, and almost 7% in 2000 but then fell back to around 6% in 2006.

In the United States, business support for academic R&D was about 4% in the early 1980s and rose to about 7% later in that decade and through the 1990s but has dropped under 6% since 2000. Some commentators note with concern this recent trend of decline, in light of the significant role that academic basic research plays in providing a foundation for technological innovation important to the national economy.

The proportion of academic R&D financed by business is more varied among the other top R&D-performing countries (figure 4-19). The highest figures for business support of academic R&D are currently in China (35%) and Russia (31%). The figures are also high in Germany (14%) and South Korea (14%), whereas Japan, France, and Italy occupy the low end, with figures in the 1% to 3% range.

S&E Fields

Many countries that support a substantial level of academic R&D devote proportionately more of their R&D spending to engineering and social science than does the United States (table 4-16). The thrust of U.S. academic R&D support is more directed at the natural and medical sciences. (For a more detailed discussion of S&E field patterns of academic research in the United States and other countries, see chapter 5, "Outputs of S&E Research.")

Government R&D Priorities

Public R&D budget directed toward specific socioeconomic objectives gives insight into government priorities. Statistics compiled by the OECD on annual government

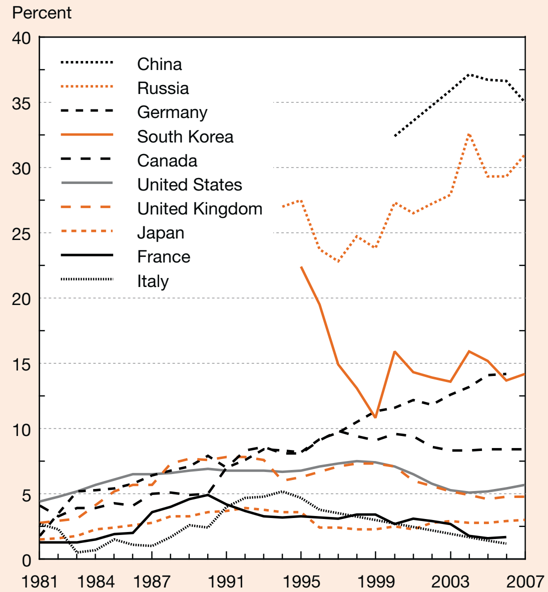
Government Funding Mechanisms for Academic Research

U.S. universities generally do not maintain data on departmental research (i.e., research which is not separately budgeted and accounted). As such, U.S. R&D totals are understated relative to the R&D effort reported for other countries. The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants provided by all levels of government to the academic sector. These funds can support departmental R&D programs that are not separately budgeted. GUF is not equivalent to basic research. The U.S. federal government does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects, usually to address the objectives of the federal agencies that provide the R&D funds. However, some state government funding probably does support departmental research at U.S. public universities.

The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through large block grants that are used at the discretion of each higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Moreover, government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds that can be assigned to specific socioeconomic categories).

In the United States, the federal government is much more directly involved in choosing which academic research projects are supported than are national governments in Europe and elsewhere—although this is not necessarily the case with state governments. In several European G-7 countries (France, Germany, Italy, and the United Kingdom), GUF accounts for 50% or more of total government R&D funding to universities. In Canada, GUF accounts for about 38% of government academic R&D support. These data reflect not only the relative international funding priorities but also the funding mechanisms and philosophies regarded as the best methods for financing academic research.

Figure 4-19
Academic R&D financed by business for selected countries: 1981–2007



NOTES: Data for top 10 R&D performing countries. Data not available for all countries for all years. Japan data for 1996 onward may not be comparable with earlier years because of changes in methodology.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

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budget appropriations or outlays for R&D (GBAORD) for its members and selected other countries provide a basis for such a comparison (table 4-17).

Defense is an objective for government funding of R&D for all the top R&D-performing countries, but the share varies widely. Defense accounted for 58% of U.S. federal R&D support in 2007 but was markedly lower elsewhere: a smaller but still significant 29% in France and 28% in the United Kingdom, 17% in South Korea, and below 10% in both Germany and Japan.

Defense has remained the focus of more than 50% of the federal R&D budget in the United States for much of the past 25 years. It was 63% in 1990 as the long Cold War period drew to a close. It dropped to 52% in 2000 but has risen again in the wake of events stemming from September 11, 2001. The defense share of government R&D funding for the other countries over the past 25 years has generally declined or remained at a stable, low level.

The health and environment objective now accounts for 55% of nondefense federal R&D budget support in the United States and 26% in the United Kingdom. For both countries, the share has expanded dramatically over the prevailing levels several decades ago. The health and environment share is currently 17% in South Korea, 13% in France, and 10% or less in Germany and Japan. The funding under this objective goes primarily into the health arena in the United States and the United Kingdom. In the other countries, it is more balanced between health and the environment.

The economic development objective encompasses agriculture, fisheries and forestry, industry, infrastructure, and energy. The share of nondefense government R&D support

Table 4-16
Share of academic R&D expenditures, by country and S&E field: Most recent year
(Percent distribution)

Field	U.S. (2007)	Japan (2006)	Germany (2002)	Russia (2007)	Canada (2005)	Taiwan (2006)	Spain (2006)	Australia (2006)	Sweden (2005)
Academic R&D expenditure (PPP $billions)	50.24	17.62	9.64	1.59	8.16	2.03	4.31	3.83	2.34
Academic R&D	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NS&E	91.2	67.4	78.8	81.4	80.3	86.3	63.1	74.0	78.9
Natural sciences	37.6	11.6	29.2	29.4	NA	17.9	23.1	29.9	19.2
Engineering	15.0	24.5	20.3	46.8	NA	40.9	23.4	11.7	22.8
Medical sciences	32.9	26.8	25.2	3.0	NA	19.9	14.1	26.9	31.8
Agricultural sciences	5.8	4.6	4.1	2.2	NA	7.6	2.5	5.4	5.1
Social sciences and humanities	6.7	32.6	20.7	18.6	19.7	13.7	36.9	26.0	19.5
Social sciences	6.5	NA	8.4	13.5	NA	10.8	22.3	20.5	13.1
Humanities	0.1	NA	12.4	5.1	NA	2.9	14.6	5.5	6.3
Academic R&D nec	2.1	NA	0.4	NA	NA	NA	NA	NA	1.6
Academic NS&E									
NS&E	100.0	100.0	100.0	100.0	NA	100.0	100.0	100.0	100.0
Natural sciences	41.2	17.2	37.0	36.2	NA	20.8	36.6	40.5	24.3
Engineering	16.4	36.3	25.8	57.5	NA	47.4	37.2	15.8	28.9
Medical sciences	36.0	39.7	32.0	3.6	NA	23.0	22.3	36.4	40.3
Agricultural sciences	6.3	6.8	5.2	2.7	NA	8.9	3.9	7.3	6.5

NA = not available

nec = not elsewhere classified; NS&E = natural sciences and engineering; PPP = purchasing power parity

NOTES: Data for following top 10 R&D-performing countries not available: China, France, South Korea, United Kingdom, and Italy. Additional countries included in top 15 of R&D-performance. Detail may not add to total because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: FY 2007 (2009); and Organisation for Economic Co-operation and Development (OECD), OECD.Stat database, accessed 6 March 2009.

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allocated to economic development has generally declined over the past 25 years across the OECD countries. In the United States, it was 36% of all nondefense federal support for R&D in 1981, dropping to 10% in 2007.[34] In the United Kingdom, it was 39% in 1981, declining to 7% in 2006. Despite a decline, support for this objective remains substantial in some countries: 22% in Germany and France (both with particular attention to industrial production and technology) and 31% in Japan (notably in energy and industrial production and technology). South Korea currently has by far the largest share for this objective, 52%, with a particularly strong emphasis in recent years on industrial production and technology.

The civil space objective accounts for 18% of nondefense federal R&D funding in the United States. The share has been around 20% in the United States for much of the past 25 years. The share in France is currently about 13%—and has been around that level for almost 20 years. The share has been below 10% for the rest of the OECD countries.

The *other purposes* objective includes the general advance of knowledge (university research and nonoriented government research), education, and other activities directed toward cultural and socioeconomic system purposes. This objective accounts for 17% of nondefense federal R&D funding in the United States (table 4-17). The share is substantially greater elsewhere: 64% in Germany and the United Kingdom, 55% in Japan, and 52% in France. For all OECD countries, university research and nonoriented government research constitute the vast majority of the funding under this objective.

R&D by Multinational Companies

Foreign direct investment (FDI) refers to the ownership of productive assets outside the home country by MNCs. (See sidebar "Foreign Direct Investment in R&D.") FDI and international trade are key channels for international knowledge and technology diffusion, which in turn contribute to productivity growth (Keller 2004; OECD 2008a). Globalization of R&D through FDI activities by MNCs reflects a decentralized model of innovation that takes advantage of location-specific skills while seeking to retain the benefits

Table 4-17
Government R&D support by major socioeconomic objectives, for selected countries: 1981–most recent year
(Percent)

Country/economy and year	GBAORD (current US$millions, PPP)	GBAORD budget shares: Defense	GBAORD budget shares: Nondefense	Nondefense R&D budget shares: Health and environ-ment	Nondefense R&D budget shares: Economic development programs	Nondefense R&D budget shares: Civil space	Nondefense R&D budget shares: Other purposes
OECD							
1981	68,423.0	37.7	62.3	17.8	37.7	10.2	34.3
1990	135,732.9	39.3	60.7	18.8	28.9	11.8	40.5
2000	196,850.7	28.2	71.8	22.3	23.0	10.0	44.7
Most recent (2006)	287,197.0	33.2	66.8	25.3	21.6	9.3	43.8
United States							
1981	33,735.0	56.4	45.4	31.2	36.1	20.3	12.4
1990	63,781.0	62.6	37.4	40.2	22.2	24.2	13.4
2000	83,612.5	51.6	48.4	49.9	13.4	20.9	15.8
Most recent (2007)	141,890.3	57.8	42.2	54.7	10.3	18.4	16.6
European Union-27							
1981	na	na	na	na	na	na	na
1990	na	na	na	na	na	na	na
2000	75,267.4	13.1	86.9	11.6	22.7	6.1	59.6
Most recent (2006)	96,995.8	13.3	86.7	13.7	22.3	5.4	58.6
Germany							
1981	8,572.5	8.9	91.1	9.6	34.9	4.6	50.9
1990	13,269.1	13.5	86.5	10.8	25.9	6.8	56.5
2000	16,787.5	7.8	92.2	9.4	21.6	4.9	64.1
Most recent (2007)	20,837.7	6.1	93.9	9.7	21.6	5.0	63.7
France							
1981	7,211.8	38.4	61.6	13.3	37.9	6.7	42.1
1990	13,738.9	40.1	60.0	9.3	32.8	13	44.9
2000	14,721.6	21.4	78.6	9.7	17.7	14.2	58.4
Most recent (2007)	15,538.5	28.8	71.2	13.2	21.9	12.6	52.3
United Kingdom							
1981	6,791.4	46.3	53.7	13.1	38.5	3.8	44.6
1990	8,154.7	43.5	56.5	18.1	31.9	5.5	44.5
2000	10,346.0	36.2	63.8	28.3	12.1	3.7	55.9
Most recent (2006)	14,768.8	28.3	71.7	25.8	7.1	3.0	64.1
Japan							
1981	NA	NA	NA	NA	NA	NA	NA
1990	10,255.4	5.4	94.6	4.5	33.9	6.9	54.7
2000	21,196.9	4.1	95.9	6.6	33.4	5.8	54.2
Most recent (2007)	29,184.8	4.5	95.5	7.1	30.6	7.3	55.0
South Korea							
1981	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA
2000	5,007.2	20.5	79.5	14.8	53.4	3.1	28.7
Most recent (2007)	10,831.9	16.6	83.4	17.1	52.4	4.6	25.9

na = not applicable; NA = not available

GBAORD = government budget appropriations or outlays for R&D; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTES: Nondefense R&D classified as other purposes consists primarily of general advancement of knowledge (university funds and nonoriented research programs). GBAORD figures not currently available for China and incomplete for Russian Federation. See appendix table 4-30.

SOURCE: OECD, Main Science and Technology Indicators (2008/2).

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Foreign Direct Investment in R&D

Direct investment is defined as ownership or control of 10% or more of the voting securities of a business (affiliate) in another country. As with other overseas activity, the geographic distribution of affiliates' R&D varies by investing country and industry (OECD 2007). FDI in R&D is driven by factors ranging from costs and long-term market and technological opportunities to infrastructure and policy considerations, such as availability of appropriately trained human resources and intellectual property protection (Niosi 1999; Thursby and Thursby 2006; von Zedtwitz and Gassmann 2002).

Statistics on R&D by affiliates of foreign companies located in the United States, and by foreign affiliates of U.S. MNCs and their parent companies, can be obtained from BEA's Survey of Foreign Direct Investment in the United States (FDIUS) and BEA's Survey of U.S. Direct Investment Abroad (USDIA). BEA data used in this section cover nonbank companies.* Affiliate data cover majority-owned affiliates, that is, those in which the ownership stake of parent companies totals more than 50%. Annual changes in FDI R&D reflect a combination of mergers and acquisitions; newly built factories, service centers, or laboratories; and activities in existing facilities. Available data do not, however, allow for distinguishing among these alternative investments.†

*Nonbank data exclude activities by companies classified in depository credit intermediation, which comprises commercial banks, savings institutions, credit unions, bank holding companies, and financial holding companies.

†For detailed methodology, see http://www.bea.gov/international/usdia2004f.html (USDIA) and http://www.bea.gov/scb/pdf/internat/fdinvest/meth/FDIUS2002Benchmark.pdf (FDIUS).

of common ownership and control.[35] Overseas locations may also facilitate networking opportunities with foreign companies, research centers, and universities. Thus, R&D by MNCs complements activities with external parties, such as R&D contracting, technology alliances, and international exchanges of R&D services, discussed later in this chapter. As a whole, these activities reflect a collaborative and global framework for creating and exploiting new knowledge by leveraging internal and external capabilities (OECD 2008a).

As described below, according to Bureau of Economic Analysis (BEA) data, the majority of R&D by U.S. MNCs continues to be performed in the United States. Western Europe has attracted the majority of U.S.-owned overseas R&D, followed by the Asia-Pacific region.[36] Likewise, foreign-owned companies continue to invest in R&D in the United States.

Linking MNC Data From International Investment and Industrial R&D Surveys

An ongoing data development project aims to integrate the statistical information from BEA's international investment surveys with the NSF/Census Survey of Industrial Research and Development. Combining technological and investment data from these complementary sources will facilitate a better assessment of globalization trends in R&D and technological innovation. The initial methodological study demonstrated the feasibility and utility of such a linkage.

A combined preliminary data set provided information for the first time on R&D expenditures by U.S. and foreign MNCs by character of work (basic research, applied research, and development). The study has also produced tangible benefits for the participating agencies, including improvements in survey sampling and the quality of reported data. These promising initial results have prompted the three participating agencies to continue work in this area. For more information, see NSF/SRS (2007b) and Census Bureau et al. (2005).

U.S. Affiliates of Foreign Companies

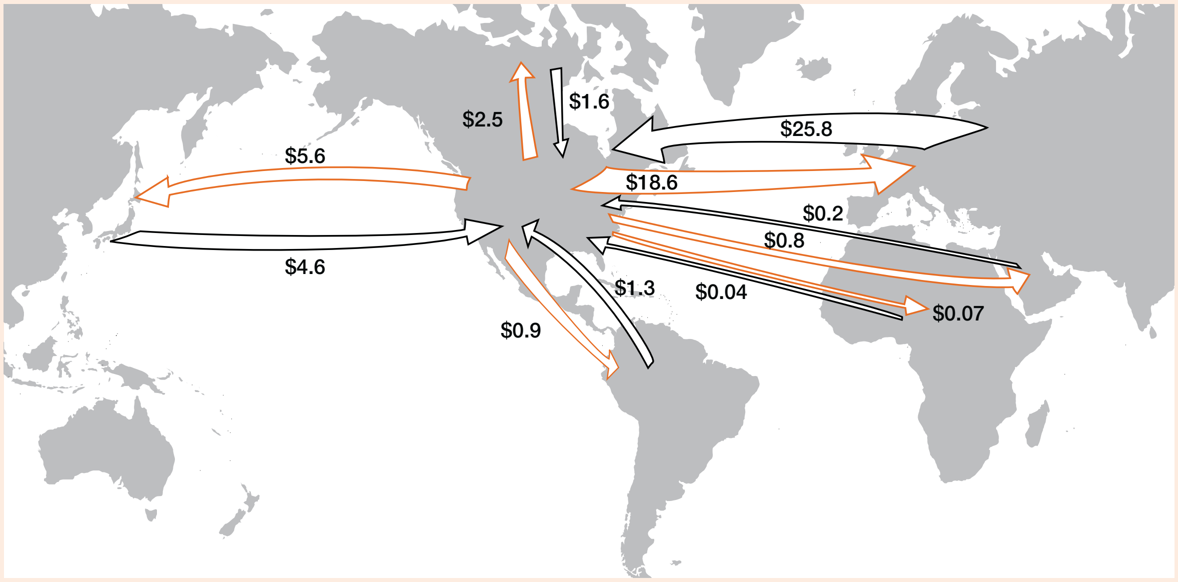
R&D performed by majority-owned affiliates of foreign companies located in the United States (U.S. affiliates) reached $34.3 billion in 2006, compared with $31.1 billion in 2005 (appendix table 4-32).[37] R&D expenditures by these companies grew at an annual average rate of 11.3% (8.6% after adjusting for inflation) from 1987 to 2006, more than double the 5.3% (2.8%) rate for total business R&D performed in the United States. This faster growth rate increased their share in total business R&D from the single digits in the early 1990s to 14.8% in 2003; their share has hovered near 14% since then. Details on the R&D character of work for MNCs are under development. (See sidebar "Linking MNC Data From International Investment and Industrial R&D Surveys.")

Since the late 1980s, European subsidiaries have performed about three-fourths of all U.S. affiliates' R&D ($25.8 billion in 2006) (figure 4-20). The share of Japanese-owned companies grew from the single digits in the late 1980s to between 10% and 12% since 1996. European and Japanese subsidiaries combined have accounted for more than 85% of these expenditures since 2001.

In 2006, manufacturing accounted for about three-quarters of U.S. affiliates' R&D, including 37% in chemicals (of which pharmaceuticals was 90%), 12% in transportation equipment, and 9% in computer and electronic products (table 4-18; appendix table 4-33). These three industries also topped overall U.S. business R&D.

Figure 4-20
R&D performed by U.S. affiliates of foreign companies in United States, by investing region, and performed by foreign affiliates of U.S. multinational corporations, by host region: 2006

(Billions of current U.S. dollars)



NOTES: Preliminary estimates.

SOURCES: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series); and Survey of U.S. Direct Investment Abroad (annual series). See appendix tables 4-32 and 4-34.

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Table 4-18
R&D performed by majority-owned affiliates of foreign companies in United States, by selected NAICS industry of affiliate and country/region: 2006
(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing	
Country/region	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Transportation equipment	Information	Professional, technical, scientific services
All countries	34,257	25,035	12,750	789	3,072	1,329	4,198	967	1,879
Canada	1,586	295	D	11	D	D	D	D	83 e
Europe	25,803	22,121	12,168	637	2,568	1,226	3,697	592	729
France	3,335	2,978	D	D	575	D	180 e	165	D
Germany	6,742	5,880	1,761	99	121	D	2,812	D	D
Netherlands	1,562	D	D	D	D	2	D	0	4
Switzerland	5,039	4,483	4,248	44	D	D	5	2	D
United Kingdom	6,801	6,357	3,836	45 e	1,682	28	491	D	110 e
Asia/Pacific	4,589	1,475	409	D	380	39 e	D	D	986
Japan	3,995	1,258	396	58	295	38 e	262	18 e	819
Latin America/OWH	D	920	2 e	D	D	D	4 e	3	D
Middle East	D	161	D	1	D	0	9	D	0
Africa	35	D	D	0	0	0	0	D	0

D = suppressed to avoid disclosure of confidential information; e = >50% of value for data cell estimated to account for data not reported by respondents

NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2006 estimates for majority-owned (>50%) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Expenditures included for R&D conducted by foreign affiliates, whether for themselves or others under contract. Expenditures excluded for R&D conducted by others for affiliates under contract.

SOURCE: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/international/index.htm#omc, accessed 6 May 2009.

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Statistics from 2006 indicate that affiliates from different countries emphasized R&D in different industries. German-owned affiliates located in the United States spent more than 40% of their $6.7 billion R&D in transportation equipment (table 4-18). British-owned companies accounted for more than half of affiliates' R&D in computers and electronic products. Japanese-owned firms accounted for 44% of affiliates' R&D expenditures in professional, scientific, and technical services. Swiss-owned firms performed a third of affiliates' R&D in pharmaceuticals.

U.S. MNCs and Their Overseas R&D

U.S. MNCs (parent companies and their foreign affiliates) performed $216.3 billion in R&D worldwide in 2006 (table 4-19). Parents of U.S. MNCs performed $187.8 billion in R&D, compared with $177.6 billion in 2005, a 2.5% increase on an inflation-adjusted basis.[38] The 2006 R&D by MNC parents represented 87% of global R&D by U.S. MNCs and about 76% of U.S. business R&D. Both shares have changed little since 2004.[39]

Overseas R&D performed by majority-owned foreign affiliates (henceforth, foreign affiliates) reached $28.5 billion in 2006, compared with $27.7 billion in 2005 (essentially unchanged on an inflation-adjusted basis). However, since 1999 foreign affiliates' R&D expenditures increased at a 4.0% annual average rate after adjusting for inflation, and have increased at a 5.0% annual average rate since 1994.

In 2006, affiliates located in Europe accounted for 65% ($18.6 billion of $28.5 billion) of overseas affiliates' R&D, of which the United Kingdom and Germany combined represented more than half ($10.3 billion) (appendix table 4-34).[40] Europe's share, however, is down from 73% in 1994 (figure 4-21).

Indeed, the geographic distribution of R&D by overseas affiliates of U.S. MNCs is gradually reflecting the role of emerging markets in global R&D (figure 4-21).[41] In particular, major developed economies or regions (Canada, Europe, and Japan) account for a decreasing share of the overseas R&D investments of U.S. MNCs, declining from 90% in 1994 to 80% in 2006. Over the same period, the share of the region termed *Asia except Japan* more than doubled, from

Table 4-19
R&D performed by U.S. multinational companies: 2004–06

Year	R&D performed (current US$millions) U.S. parents	MOFAs	Total MNCs	Shares of MNC (%) U.S. parents	MOFAs
2004.....	164,189	25,840	190,029	86.4	13.6
2005.....	177,598	27,653	205,251	86.5	13.5
2006.....	187,813	28,484	216,297	86.8	13.2

MNC = multinational company; MOFA = majority-owned foreign affiliate

NOTE: MOFAs are affiliates in which combined ownership of all U.S. parents is >50%.

SOURCE: Bureau of Economic Analysis. Survey of Foreign Direct Investment in the United States (annual series). See appendix tables 4-34 and 4-36.

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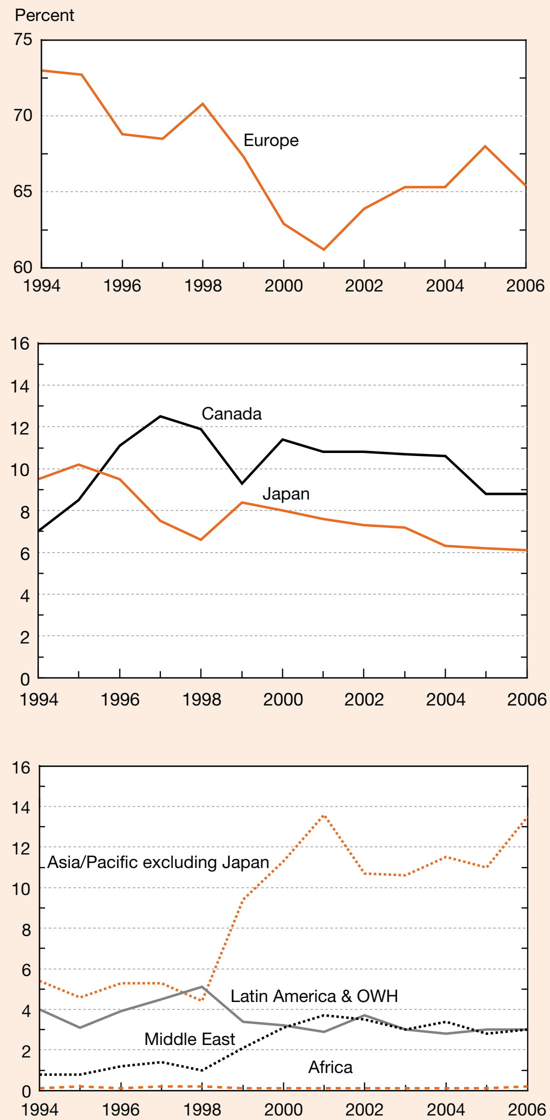
Figure 4-21
Regional shares of R&D performed abroad by foreign affiliates of U.S. MNCs: 1994–2006



MNC = multinational company; OWH = other Western Hemisphere

NOTES: Data for majority-owned affiliates. Preliminary estimates for 2006.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series).

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5.4% to 13.5%, driven by the R&D spending of U.S.-owned affiliates in China, Singapore, and South Korea.

On an individual country basis, changes proved more modest in terms of global shares, although funding levels in some lower-cost locations may still be significant from the perspective of purchasing power. R&D performed by U.S.-owned affiliates in China and India increased from less than $10 million in each country in 1994 to $804 million in China and $310 million in India in 2006, but these levels represented only about 3% and 1%, respectively, of total overseas R&D by U.S. MNCs. In the Middle East, Israel accounted for virtually all R&D by affiliates of U.S. MNCs, with about 3% of the global share. Brazil represented two-thirds of Latin America's U.S.-owned affiliates' R&D and a 2% global share.

In 2006, manufacturing affiliates accounted for 83% of overseas affiliates' R&D, including 68% by three manufacturing industries: transportation equipment (29%), chemicals (including pharmaceuticals) (22%), and computer and electronic products (17%) (table 4-20). More than half of R&D by U.S.-owned affiliates in Europe was performed by affiliates classified in transportation equipment (35%) and chemicals (21%). Affiliates classified in transportation equipment also performed half of U.S.-owned R&D in

Table 4-20
R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies, by selected NAICS industry of affiliate and country/region: 2006
(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing	
Country/region	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Information	Professional, technical, scientific services
All countries	28,484	23,638	6,166	1,128	4,874	651	8,342	1,014	2,688
Canada	2,503	1,766	759	37	260	14	587	271	415
Europe	18,628	15,635	3,882	830	1,976	503	6,460	374	1,790
Belgium	948	699	D	15	D	D	26	3	226
France	1,447	1,287	313	110	206	28	392	29	78
Germany	4,919	4,754	253	279	609	245	2,888	22	100
Ireland	848	538	234	0	225	4	5	204	D
Italy	689	587	274	84	21	42	86	*	84
Netherlands	486	426	184	26	35	D	D	8	38
Sweden	1,536	1,512	72	8	68	20	D	1	19
Switzerland	933	501	254	52	61	4	6	D	D
United Kingdom	5,378	4,296	1,412	200	632	71	1,582	77	862
Asia and Pacific	5,575	4,680	1,233	D	2,105	129	849	D	D
Australia	596	536	162	D	D	1	D	1	28
China	804	675	30	15	541	35	30	D	D
Hong Kong	105	47	D	0	16	D	0	4	50
India	310	106	8	13	D	*	20	D	108
Japan	1,739	1,560	893	10	397	D	92	111	16
Korea	729	704	34	15	201	D	D	D	1
Malaysia	249	248	3	*	241	1	0	0	*
Singapore	850	634	D	*	564	2	D	D	D
Latin America/OWH	865	811	242	50	27	6	419	*	20
Brazil	571	539	136	48	18	4	307	0	11
Middle East	847	693	29	D	506	0	0	D	D
Israel	846	693	29	D	506	0	0	D	D
Africa	65	53	21	1	0	*	26	2	*
South Africa	52	42	19	1	0	*	D	2	*

D = suppressed to avoid disclosure of confidential information; * = ≤ $500,000

NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2006 estimates for majority-owned (>50%) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Expenditures included for R&D conducted by foreign affiliates, whether for themselves or others under contract. Expenditures exclue for R&D conducted by others for affiliates under contract.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/international/index.htm#omc, accessed 6 May 2009.

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Brazil. Affiliates classified in chemicals performed half of R&D by U.S.-owned companies in Japan.

Reflecting the increasing global linkages in information technology production and development, affiliates classified in computer and electronic product manufacturing performed the majority of U.S.-owned R&D in some emerging markets: Malaysia (97%), China (67%), Singapore (66%), and Israel (60%) (table 4-20). In terms of service industries, affiliates classified in the information industry (which includes software and Internet publishers and telecommunications) performed about one-fourth of U.S.-owned R&D in Ireland. Finally, 35% of R&D by U.S.-owned affiliates in India was performed by those classified in professional, scientific, and technical services (which includes computer and scientific R&D services).[42] Nevertheless, European-located affiliates performed two-thirds of the $2.7 billion in overseas, U.S.-owned R&D in this industry.

Technology and Innovation Linkages

Increasingly, R&D and innovation are pursued in a collaborative and interactive environment, often embedded in global supply, production, and distribution networks (Dahlander and Gann 2007; Howells 2008; OECD 2008a). This section presents indicators on two types of innovation linkages: (1) business-to-business interactions in the form of contracted-out R&D, international transactions in R&D services, and global technology alliances, and (2) public-private collaborations. Overall, these indicators illustrate a variety of intra- and cross-organizational arrangements intended to absorb, manage, and exploit external and/or jointly developed knowledge (Chesbrough, Birkinshaw, and Teubal 2006; Ozman 2009). For ongoing development activities related to innovation indicators, see the sidebar "Recent Developments in Innovation-Related Metrics."

Recent Developments in Innovation-Related Metrics

Interest in R&D and innovation-related metrics by governments, academic researchers, and businesses has a long history (Earl and Gault 2006) but has intensified in recent years in the United States (DOC 2008; Mandel 2008; McKinsey & Company 2008; Moris, Jankowski, and Perolle 2008; NRC 2005a; NSF/TCB 2008) and elsewhere (Gault and von Hippel 2009; OECD 2008c). Recent developments in innovation-related metrics are driven by a number of factors, including:

- The rapidly evolving nature of innovation in terms of joint production and exploitation of knowledge, user-based innovation, new business models, entrepreneurship, and global linkages
- Advances in social, behavioral, economic, and management theories of creativity, productivity, and innovation
- Developments in national standards on statistical quality and protection of confidentiality
- Emerging international accounting standards and official statistics guidance on intangibles and other nonfinancial assets
- Advances in data development, integration, and empirical research methodology involving microdata sets, administrative data, data enclaves, and new computing and visualization tools

Innovation is defined as the introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or the marketplace (OECD/Eurostat 2005, p 146). R&D is only one of many possible knowledge inputs driving innovation. For example, innovation may result from the integration of existing technology or from a new business model. Enhanced international guidance and ongoing methodological studies to better capture statistics on nontechnological innovation, innovation linkages, and service-sector activities are driving development of metrics across OECD countries.

Part of the challenge in developing new metrics resides in the broad scope of innovation activities covering inputs, processes, cross-sector linkages, immediate outputs (for example, products or patents), long-term socioeconomic impacts, and infrastructure or system-wide variables (such as policy incentives or technology standards). Accordingly, data development spans multiple strategies, including surveys and data linking and integration, as well as non-survey-based methods, such as case studies, administrative databases, and Web-based information—pursued in parallel or in combination (NSF/SRS 2007a; NSF/TCB 2008). The following describes selected activities in the development of these indicators.

Intangible Investment and GDP

Treating spending on intangibles, such as software and R&D, as investment in the national income and product accounts (NIPA) (which include GDP and other U.S. economic accounts) recognizes intangible capital, along with other forms of investment inputs, in the production of economic output (Corrado, Hulten, and Sichel 2006; UNSC 2007). International statistical manuals are being updated or developed to provide guidance for comparable measures in this area, including an updated manual for the United Nations System of National Accounts (SNA) and a new OECD handbook covering intangibles and national accounts (Aspden 2008). Software has been considered an

(continued on next page)

Business-to-Business Linkages

Technology and innovation linkages vary by type of partner or knowledge source and level of interaction (OECD/Eurostat 2005). Knowledge sources range from academic papers, conference proceedings, and reports from government laboratories to information from commercial sources, such as marketing and management consultants, patent licensors, R&D contractors, and technology vendors. This section examines indicators related to business transactions and organizational arrangements to acquire or jointly develop new knowledge.

Contract R&D Expenses Within the United States

Increasingly, companies that perform R&D in the United States contract out these activities. These companies reported an estimated $19 billion in R&D performed by external organizations located in the United States[43] in 2007, compared with $12.4 billion in 2006 (appendix tables 4-39 and 4-40).[44] The all-industries ratio of contracted-out R&D to company-funded, company-performed R&D increased from 5.5% in 2006 to 7.8% in 2007.[45] For manufacturers, the ratio reached 8.5% in 2007, up from 5.7% in 2006 (figure 4-22).

Across R&D-intensive industries, pharmaceuticals had the highest ratio of contracted-out R&D (21%) in 2007. The ratio for automotive manufacturers was 7.3%, and for navigational, measuring, electromedical, and control instruments (a subsector of the computer and electronic products industry) was 3.8%. Within services, the contracted-out R&D ratio was 13.8% for scientific R&D services and 8.3% for telecommunications in 2007.

Exports and Imports of R&D Services

Across OECD countries, international trade in services, especially those involving intangibles and knowledge-based assets, presents unique measurement challenges for both business accounting and official statistics (OECD 2008b; Reinsdorf and Slaughter 2009; Yorgason 2007). An indicator in

investment in U.S. NIPA since 1999, and BEA and NSF continue to work on an R&D satellite account, as described earlier in this chapter. BEA plans to incorporate both R&D and spending on artistic and literary originals as intangible investment in the core economic accounts in 2013 and is considering an expanded satellite account that would contain experimental statistics for other intangibles (Aizcorbe, Moylan, and Robbins 2009).

Science of Science and Innovation Policy Program, Research Data Infrastructure, and Advanced Computing Tools

The NSF Science of Science and Innovation Policy (SciSIP) program supports research designed to advance the scientific basis of science and innovation policy. Research funded by the program is aimed at developing, improving, and expanding models, analytical tools, data, and metrics. An area of interest is the development of data infrastructure to support empirical research on innovations within organizations (NSF/TCB 2008). Other efforts focus on cyber-infrastructure research; advanced computing and Web-based tools to protect, archive, link, mine, and analyze data (Lane, Heus, and Mulcahy 2008); and advanced visualization and analytical tools for document-based information, such as patents and bibliographic entries (Börner, Chen, and Boyack 2003).

Entrepreneurship and Business Dynamics

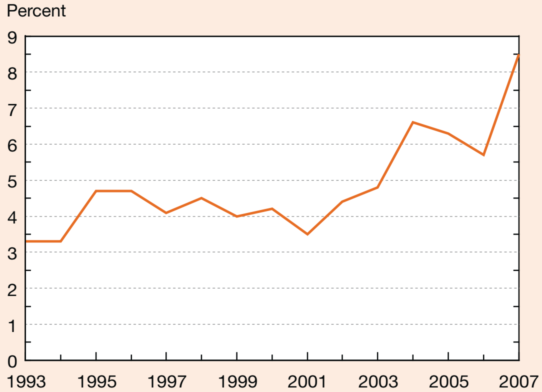
Two National Research Council (NRC) reports cite the need to leverage business data collected by statistical agencies for research and policymaking purposes by more effectively integrating data sets (NRC 2006, 2007b). Data sets for the study of business dynamics include the Census Bureau's Business Dynamics Statistics (BDS) (Census Bureau 2009) and Longitudinal Employer-Household Dynamics (LEHD) program (Abowd, Haltiwanger, and Lane 2004), along with the Business Employment Dynamics published by the Bureau of Labor Statistics (BLS 2009). Research topics of interest include technology adoption, innovation, outsourcing, globalization, market entry and exit by companies, and new or small technology-based firms. Indeed, entrepreneurship has been extensively researched as a vehicle for transferring and exploiting new knowledge from public or private sources (Audretsch 2009). In the United States, the Kauffman Foundation funds research in entrepreneurship and innovation (Kauffman 2008) and sponsors a social longitudinal survey on young firms (Kauffman 2009).

OECD Innovation Microdata Project and EU Community Innovation Surveys

The OECD innovation microdata project aims at exploiting microdata from the EU Community Innovation Surveys (CIS) for economic analysis. In recent years, research teams from different OECD countries have collaborated in applying similar methodologies to their national CIS. Expected products include analytical studies and new innovation indicators covering, for example, international technology transfer, nontechnological innovation, and intellectual property rights (OECD 2009a).

The project is part of a larger OECD Innovation Strategy initiative established in 2007; the objective is to explore strategies to harness the potential of innovation based on a better understanding of innovation. Research is focusing on markets and governance, human capital, global dimensions, and the changing nature of innovation, along with measurement, reporting, and assessment of innovation (OECD 2009b)

Figure 4-22
R&D contracted out in United States by manufacturing companies as ratio of company-funded and -performed R&D: 1993–2007



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series). See appendix table 4-39.

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this area is international trade in research, development, and testing (RDT) services, including transactions among unaffiliated or independent companies (unaffiliated trade) and trade within MNCs (affiliated trade). These data are part of balance-of-payment statistics and complement other fee-based transactions (such as royalties and licensing), as well as performance and funding information from R&D surveys (Moris 2009). U.S. data for total RDT trade have been available since 2001 from BEA's international transaction surveys.[46]

In 2007, total U.S. exports (affiliated and unaffiliated) of RDT services reached a record $14.7 billion, compared with record imports of $11.4 billion, resulting in a trade surplus of $3.3 billion. Affiliated trade dominates these U.S. RDT statistics (table 4-21)—which is not surprising, given the large role of MNCs (including U.S. parents and foreign-owned companies) in R&D performance. (See "R&D by Multinational Companies.") Affiliated trade in RDT has recorded between $4 billion and $4.5 billion in annual trade surpluses since 2001, compared with diminishing balances for unaffiliated trade (table 4-21). With affiliated transactions, U.S. trade surplus in RDT services is driven not by U.S. MNC parents but by the relatively high level of exports from U.S. affiliates of foreign MNCs to their foreign parents and other foreign affiliates of the parent companies (Moris 2009).

Newly available country detail shows that 62.8% of U.S. RDT exports in 2007 were purchased by European businesses and another 12.2% by Japanese businesses (appendix table 4-41). European countries accounted for virtually the same share of RDT import transactions (62.1%) in 2007, whereas Japan accounted for 5.6%. Several emerging markets appear as sources of U.S. RDT imports, namely Israel (6.2%) and India (5.3%).

International Technology Alliances

Interfirm R&D alliances, partnerships, and networks add an element of R&D co-production compared with R&D contracts or technology licensing.[47] R&D alliances may be defined as domestic or international cooperative arrangements that combine resources aimed at shared R&D objectives (Hagedoorn, Link, and Vonortas 2003).[48] U.S. restrictions on multifirm cooperative research were loosened by the 1984 National Cooperative Research Act (Public Law 98-462), followed by the 1993 National Cooperative Research and Production Act (NCPRA) (Public Law 103-42), as a way of addressing concerns about the technological leadership and international competitiveness of American firms in the early 1980s (Scott 2008).

This section features data from the Cooperative Agreements and Technology Indicators (CATI) database, which collects data on worldwide business technology partnerships.[49] It is based on public announcements and includes business alliances with an R&D or technology component, such as joint research or development agreements, R&D contracts, and equity joint ventures. The database contains counts dating back to 1980.[50]

Table 4-21
U.S. trade in research, development, and testing services: 2001–07
(Millions of dollars)

	Exports			Imports			Trade balance		
Year	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated
2001	7,610	6,564	1,046	3,389	2,664	725	4,221	3,900	321
2002	8,678	7,536	1,142	4,063	3,035	1,028	4,615	4,501	114
2003	9,467	8,291	1,176	5,071	3,761	1,310	4,396	4,530	–134
2004	9,563	8,275	1,288	5,778	3,816	1,962	3,785	4,459	–674
2005	10,431	9,135	1,296	7,239	4,950	2,289	3,192	4,185	–993
2006	12,821	11,165	1,655	9,429	6,726	2,702	3,392	4,439	–1,047
2007	14,698	12,686	2,012	11,437	8,364	3,073	3,261	4,322	–1,061

SOURCE: Bureau of Economic Analysis, U.S. International Services, http://www.bea.gov/international/intlserv.htm, accessed 6 May 2009.

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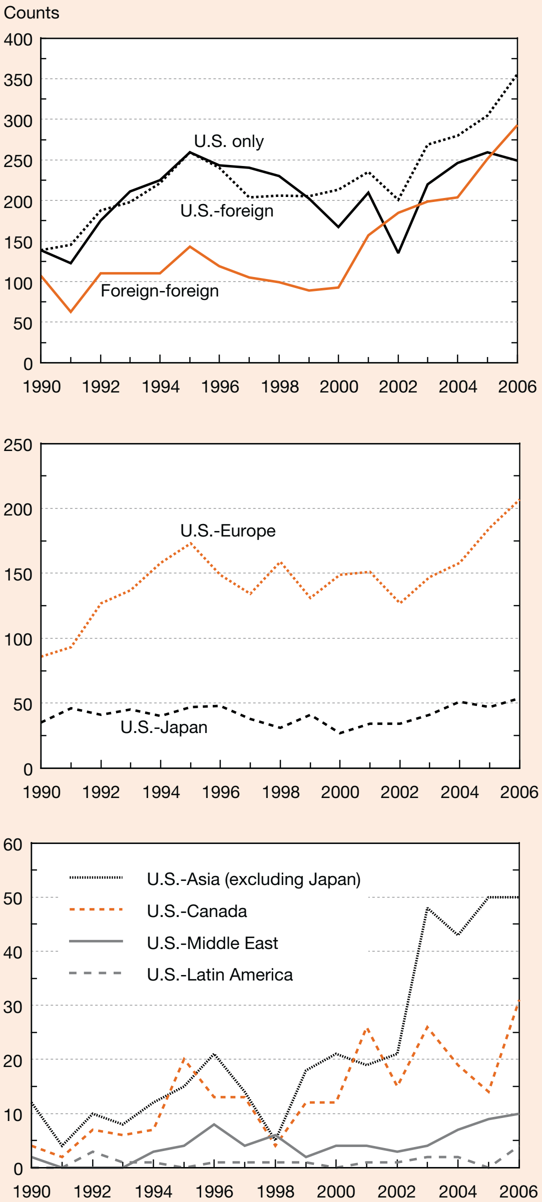
According to CATI, in 2006 (the latest available year), about 900 new worldwide business technology alliances were formed, approximately two-thirds of which involved at least one U.S.-owned company regardless of location. Close to 60% of the worldwide total focused on biotechnology, and 23% focused on information technology (appendix table 4-42). Other areas include materials research and engineering, aerospace, automotive, and chemicals. In terms of ownership, the 2006 counts can be grouped into alliances involving only U.S.-owned companies (249), U.S. and foreign-owned companies (356), and only foreign-owned companies (293).

Figure 4-23
U.S. industrial technology alliances with U.S. and foreign-owned companies, worldwide, by country/region of partner: 1990–2006



NOTE: Annual counts of new alliances.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database. See appendix table 4-42.

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Since 1999, the proportion of U.S.-foreign alliances annually has surpassed U.S.-only alliances, driven by rapid growth in U.S. alliances with European-owned companies (figure 4-23). The U.S.-Europe alliances increased 141% from 1990 to 2006, compared with about an 80% increase in U.S.-only alliances. The predominance of U.S. and European companies in CATI technology agreements is consistent with rankings of global R&D by major pharmaceutical, biotechnology, software, and automotive MNCs (UK DIUS 2008). At the same time, the number of U.S.-Japan alliances in 2006 (54) effectively reached parity with U.S. alliances with other Asia-Pacific countries (50), (reflecting the rapid growth of the latter since 1990, albeit from relatively low levels (figure 4-23). The 50 U.S. alliances with Asia-Pacific companies, excluding Japan, were driven by collaborative agreements with companies headquartered in India (15), China (12), and South Korea (11). This pattern reflects the increasing if still modest role of these countries as hosts for U.S.-owned R&D discussed earlier in this chapter. Of course, noting simple frequencies of international collaborative agreements is only a first step in tracking the economic and policy relevance for participating companies and their home and host countries (Bozeman and Dietz 2001; Siegel 2003).[51]

Federal Technology Transfer and Other Innovation-Related Programs

This section reviews two sets of indicators on public-private collaboration supporting technology transfer and innovation (for academic patents and related knowledge diffusion indicators, see chapter 5).[52] The first set includes federal programs for technology transfer from R&D funded and performed by government agencies and laboratories. The second set includes federal programs that support new or small U.S. companies in R&D or technology deployment activities with R&D funds or technical assistance.

In the late 1970s, concerns about the strength of U.S. industries and their ability to be competitive in the global economy intensified. Issues included the question of whether inventions from federally funded academic research were adequately exploited for the benefit of the national economy and the need to create or strengthen public-private R&D partnerships. Since the 1980s, several U.S. policies have facilitated cross-sector R&D collaboration and technology transfer. One major policy thrust was to enhance formal mechanisms for transferring knowledge arising from federally funded and performed R&D (Crow and Bozeman 1998; NRC 2003). Other policies addressed federally funded academic R&D, the transition of early-stage technologies into the marketplace, and R&D and innovation by small or minority-owned businesses. For a brief overview of these

Major Federal Legislation Related to Technology Transfer and Cooperative R&D

Technology Innovation Act of 1980 (Stevenson-Wydler Act) (Public Law 96-480)—established technology transfer as a federal government mission by directing federal labs to facilitate the transfer of federally-owned and originated technology to nonfederal parties.

University and Small Business Patent Procedures Act of 1980 (Bayh-Dole Act) (Public Law 96-517)—permitted small businesses, universities, and nonprofits to obtain titles to inventions developed with federal funds. Also permitted government-owned and government-operated laboratories to grant exclusive patent rights to commercial organizations.

Small Business Innovation Development Act of 1982 (Public Law 97-219)—established the Small Business Innovation Research (SBIR) program, which required federal agencies to set aside funds for small businesses to engage in R&D connected to agency missions.

National Cooperative Research Act of 1984 (Public Law 98-462)—encouraged U.S. firms to collaborate in generic precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures.

Patent and Trademark Clarification Act of 1984 (Public Law 98-620)—provided further amendments to the Stevenson-Wydler Act and the Bayh-Dole Act regarding the use of patents and licenses to implement technology transfer.

Federal Technology Transfer Act of 1986 (Public Law 99-502)—enabled federal laboratories to enter cooperative research and development agreements (CRADAs) with outside parties and to negotiate licenses for patented inventions made at the laboratory.

Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418)—in addition to measures on trade and intellectual property protection, the act directed attention to public-private cooperation on R&D, technology transfer, and commercialization. It also established NIST's Manufacturing Extension Partnership (MEP) program.

National Competitiveness Technology Transfer Act of 1989 (Public Law 101-189)—amended the Federal Technology Transfer Act to expand the use of CRADAs to include government-owned, contractor-operated federal laboratories and to increase nondisclosure provisions.

National Cooperative Research and Production Act of 1993 (Public Law 103-42)—relaxed restrictions on cooperative production activities, which enable research joint venture participants to work together in the application of technologies they jointly acquire.

National Technology Transfer and Advancement Act of 1995 (Public Law 104-113)—amended the Stevenson-Wydler Act to make CRADAs more attractive to federal laboratories, scientists, and private industry.

Technology Transfer Commercialization Act of 2000 (Public Law 106-404)—broadened CRADA licensing authority to make such agreements more attractive to private industry and increase the transfer of federal technology. Established procedures for performance reporting and monitoring by federal agencies on technology transfer activities.

America COMPETES Act of 2007 (America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Sciences [COMPETES] Act) (Public Law 110-69)—increased investment in R&D; strengthened educational opportunities in science, technology, engineering, and mathematics from elementary through graduate school; and further developed the nation's innovation infrastructure. Among other measures, the act established NIST's Technology Innovation Program (TIP) and called for a President's Council on Innovation and Competitiveness.

initiatives, see the sidebar "Major Federal Legislation Related to Technology Transfer and Cooperative R&D."

Federal Technology Transfer

Federal technology transfer refers to processes through which the knowledge and capabilities of federal intramural laboratories and other research facilities can be directed to the R&D needs of outside public or private organizations—and through which the inventions and other intellectual assets arising from federal laboratory R&D can be conveyed to outside parties for development and commercialization (FLC 2006). Since the Stevenson-Wydler Act of 1980, all federal labs have been required to have technology transfer offices (Office of Research and Technology Applications [ORTA]) to assist in identifying transfer opportunities and establishing appropriate arrangements for relationships with external parties.[53] Indicators on these activities illustrate a diverse range of mechanisms used in federal technology transfer.[54] For background information, see the sidebar "Federal Technology Transfer: Activities and Metrics."

Table 4-22 shows total technology transfer activity statistics for FY 2007, as well as statistics for six agencies that account for the majority of this activity. In 2007, federal laboratories participated in 7,327 cooperative research and development agreements (CRADAs) with businesses and organizations, compared with 7,271 in 2006 and 5,949 in 2005 (appendix table 4-43). Federal labs also participated in 9,445 non-CRADA collaborative R&D relationships in 2007. Agencies issued more than 1,400 patents in 2007 and held 10,347 active licenses, including just below 4,000

Federal Technology Transfer: Activities and Metrics

Federal technology transfer can take a variety of forms (FLC 2006), including the following:

- *Commercial transfer.* Movement of knowledge or technology is developed by a federal lab and transferred to private organizations in the commercial marketplace.
- *Scientific dissemination.* Publications, conference papers, and working papers are distributed, and other forms of data dissemination are employed.
- *Export of resources.* Federal lab personnel are made available to outside organizations with R&D needs through collaborative agreements or other service mechanisms.
- *Import of resources.* The federal lab brings in outside technology or expertise to enhance the lab's existing capabilities.
- *Dual use.* Technologies, products, or families of products with both commercial and federal applications are developed.

Most federal labs engage in all of these forms of technology transfer to some extent. The emphases and relative levels of each vary widely across the federal agencies, depending on the parent agency's mission, the lab's main areas of scientific and technological interest, typical clients, prevailing scientific/technical culture, and any special transfer authorities the agency may have been granted. For some agencies and their labs, the principal technology transfer thrust is patents, patent licenses, and material transfer agreements. Others emphasize traditional public dissemination of new scientific or technical knowledge and cooperative R&D relationships with outside organizations—with patenting and licensing activity taking place only when it is determined that private-sector investment in a new technology is needed to achieve development and commercialization goals.

Several metrics illustrate activities and agency priorities among three main classes of mechanisms. The *invention disclosure and patenting* category involves counts of invention disclosures filed (typically, an inventing scientist or engineer filing a written notice of the invention with the lab's technology transfer office), patent applications filed with the U.S. Patent and Trademark Office (or abroad), and patent awards received. The *licensing* category covers federal lab licensing of federal intellectual property, such as patents or copyrights, to outside parties to enable further development and commercialization, usually through the technology transfer office. For example, in recent years, DOE's government-owned, contractor-operated laboratories have increasingly used their special authority to transfer software technology through relatively quickly executed copyright license mechanisms. The third main category is *collaborative relationships for R&D*, including CRADAs.

Table 4-22
Federal laboratory technology transfer activity indicators, by selected U.S. agency: FY 2007

Technology transfer activity indicator	Total	DOD	HHS	DOE	NASA	USDA	DOC
Invention disclosures and patenting							
Inventions disclosed	4,486	838	447	1,575	1,268	126	32
Patent applications filed	1,824	597	261	693	105	114	7
Patents issued	1,406	425	379	441	93	37	4
Licensing							
All licenses, total active	10,347	460	1,418	5,842	1,883	339	217
Invention licenses	3,935	460	915	1,354	461	339	217
Other intellectual property licenses	6,405	0	460	4,488	1,422	0	0
Collaborative relationships for R&D							
CRADAs, total active	7,327	2,971	285	697	1	230	2,778
Traditional CRADAs	3,117	2,383	206	697	1	184	154
Other collaborative R&D relationships	9,445	0	0	0	2,666	4,084	2,695

CRADA = Cooperative Research and Development Agreement; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; USDA = U.S. Department of Agriculture

NOTES: Other federal agencies not listed but included in total: Department of the Interior, Department of Transportation, Department of Veterans Affairs, and Environmental Protection Agency. Department of Homeland Security expected to provide technology transfer statistics starting in FY 2008. Invention licenses refers to inventions that are/could be patented. Other intellectual property refers to intellectual property protected through mechanisms other than a patent, e.g., copyright. Total active CRADAs refers to agreements executed under CRADA authority (15 U.S.C. 3710a). Traditional CRADAs are collaborative R&D partnerships between a federal laboratory and one or more nonfederal organizations. Federal agencies have varying authorities for other kinds of collaborative R&D relationships.

SOURCE: National Institute of Standards and Technology, Federal Laboratory Technology Transfer, Fiscal Year 2007, Summary Report to the President and the Congress, January 2009, http://patapsco.nist.gov/ts/220/external/index.htm, accessed 6 May 2009. See appendix table 4-43.

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invention licenses, based on their total stock of intellectual property. Appendix table 4-43 provides data for all agencies for FY 2000–07.

Small Business Innovation–Related Programs

This section reviews federal programs that support new or small U.S. companies in R&D or technology deployment activities. These programs include the Small Business Innovation Research (SBIR) program, the Small Business Technology Transfer (STTR) program, the Technology Innovation Program (TIP), and the Hollings Manufacturing Extension Partnership (MEP). The first three programs provide early-stage technology financing, whereas the last one provides technical assistance to small and medium-sized manufacturers.

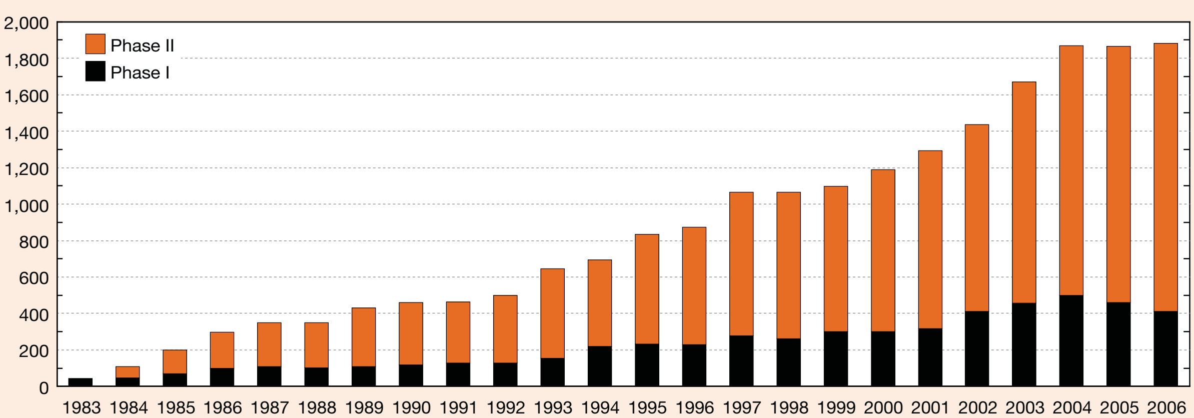
The SBIR program was created by the Small Business Innovation Development Act of 1982. According to the SBIR statute, federal agencies with extramural R&D obligations exceeding $100 million must set aside a fixed percentage of such obligations for projects involving small business (those with 500 or fewer employees). This set-aside has been 2.5% since FY 1997. The program has multiple objectives, namely stimulating technological innovation, fostering the use of small business to meet federal R&D needs, encouraging participation by minority and disadvantaged persons in technological innovation, and increasing private-sector commercialization of innovation derived from federal R&D. SBIR's sister program, the STTR program, was created in 1992 to stimulate cooperative R&D and technology transfer involving small businesses and nonprofit organizations, including universities and FFRDCs. Both of these programs are coordinated by the Small Business Administration (SBA). In FY 2007, SBIR and STTR combined awarded $2.3 billion (SBA 2009).[55]

In FY 2006, 11 federal agencies awarded a total of $1.9 billion to about 5,900 SBIR projects (appendix tables 4-44 and 4-45). Funded technology areas include computers and electronics, information services, materials, energy, and life science applications. DOD represented just below 50% of total SBIR funds, whereas HHS represented 30%, consistent with its large extramural R&D budgets.

The SBIR program is structured in three phases. Phase I evaluates the scientific and technical merit and feasibility of ideas. Phase II builds on phase I findings, is subject to further scientific and technical review, and requires a commercialization plan (NRC 2008). During phase III, the results from phase II R&D are further developed and introduced into private markets or federal procurement using private or non-SBIR federal funding.[56] Over the life of the program, the share of phase II funding has increased from about two-thirds in the mid-1980s to more than three-fourths (figure 4-24). Bridge funding and other support for startups beyond phase II were found to be critical for successful commercialization by a recent NRC study (NRC 2008, p 209). Some agencies have implemented "phase IIB" or "phase II+" matching funds and/or technical and business support for qualified awardees (NRC 2008, pp 209–16).

The STTR program is also structured in three phases and involves R&D performed jointly by small businesses and nonprofit research organizations. Federal agencies with extramural R&D budgets exceeding $1 billion participate in the STTR program. Starting in FY 2004, the required set-aside doubled to 0.3%, compared with the 2.5% set-aside for SBIR. In FY 2006, DHS participated for the first time, along with DOD, NSF, DOE, NASA, and HHS. From FY 1994 to 2006, STTR awarded $1.3 billion to about 6,000 projects, including $226 million to 878 projects in FY 2006 (appendix tables 4-44 and 4-46).

Figure 4-24
SBIR funding, by type: 1983–2006
Dollars (millions)



SBIR = Small Business Innovation Research Program

SOURCE: Small Business Administration, Small Business Innovation Research Program Annual Report (various years). See appendix table 4-45.

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According to SBA, small businesses interested in participating in the STTR program must find a research institution that meets the program's definition and develop a working agreement before competing for an STTR award. Universities are active as STTR partners. For example, in FY 2004, at least 200 universities, many with multiple awardees, partnered with small companies under STTR; 15 FFRDCs also collaborated with awardees (SBA 2005).

Established by the America COMPETES Act of 2007 and administered by NIST,[57] TIP was set up for "the purpose of assisting U.S. businesses and institutions of higher education or other organizations, such as national laboratories and nonprofit research institutions, to support, promote, and accelerate innovation in the United States through high-risk, high-reward research in areas of critical national need."[58] The new program replaces the Advanced Technology Program (ATP). From FY 1990 to 2007, ATP awarded funds for 824 projects with a combined funding of $4.6 billion, about equally split between the program and its participants (appendix table 4-47). The first TIP competition focused on advanced sensors to support monitoring and assessment of civil infrastructure, such as water pipelines, roads, bridges, and tunnels (appendix table 4-48).

A national system of affiliated manufacturing extension centers, MEP is also housed at NIST. It was established by the Omnibus Trade and Competitiveness Act of 1988 to enhance the productivity and technological performance of small and medium-sized U.S. manufacturers (15 U.S.C. 278(k)).

MEP centers receive federal funding on a competitive basis for their development and operations. Nonfederal funding is required for 50% or more of the centers' capital and annual operating funds. Companies receive technical and managerial assistance, generally on a reimbursable basis, but receive no direct federal funding (Schacht 2008). Federal funding for MEP reached $106.8 million in FY 2007 and $91 million in FY 2008 (appendix table 4-49). Activities included technology deployment and technical services involving advanced manufacturing systems and engineering services, as well as business services such as management and strategy development, marketing, and training. For nontechnical services, MEP centers generally partner with commercial and academic consultants and government agencies (Shapira 2001, pp 983–84).[59]

Conclusion

U.S. spending on R&D reached an estimated $397.6 billion in 2008, a 6.7% increase (or 4.5% in inflation-adjusted dollars) from the 2007 total. This 2008 figure is preliminary, however, and may not fully reflect the effects of the downturn in U.S. and worldwide economic conditions that took place in the latter half of the year.

In 2008, businesses performed an estimated $289.1 billion (current dollars), or 73%, of the total U.S. R&D. The academic sector is the second-largest performer of U.S. R&D, with estimated expenditures of $51.2 billion, or just below 13% of the U.S. total. Federal agencies, their laboratories, and FFRDCs accounted for an estimated $41.7 billion, or about 11% of the total. Nonprofit organizations performed the remainder, $15.6 billion, or about 4%.

Business and the federal government are the two largest sources of R&D funding. The business sector provided an estimated $267.8 billion (current dollars) of funding for R&D in 2008, 67% of the U.S. total. The federal government funded an estimated $103.7 billion of R&D, or 26% of the total. Over the past 5 years, expanded business spending on R&D has accounted for much of the growth (in both current and real-dollar terms) in total U.S. R&D spending. Federal funding overall has been flat or declining on a real-dollar basis. At the time of this writing, the impact of the current economic slowdown in U.S. R&D expenditures remains uncertain.

Historically, the federal government has been the prime source of funding for basic research, accounting for an estimated 57% of the nation's total in 2008. Moreover, in the same year, the federal government funded 61% of the basic research performed by universities and colleges, the nation's largest performers of basic research.

The budget appropriations for federal spending on R&D in FY 2009 totaled $147.1 billion, an increase of $3.3 billion, or 2.4%, over the FY 2008 spending level. The president's proposed budget for FY 2010 requests federal R&D spending of $147.6 billion, an increase of $0.6 billion, or 0.4%, over the appropriated FY 2009 level. Furthermore, the American Recovery and Reinvestment Act, enacted in early 2009, provided a one-time increase in funding for federal R&D and R&D infrastructure, estimated to total $18.3 billion in FY 2009.

Globally, R&D expenditures totaled an estimated $1,107 billion in 2007, the most recent year for which internationally comparable data are available. R&D is concentrated regionally in North America (35%), Asia (31%), and Europe (28%) and is further concentrated within a relatively few countries. According to OECD statistics, the United States (with 33% of the world total) and Japan (13%) account for almost half of global R&D. That figure increases to two-thirds by adding the next three countries on the list, China (9%), Germany (6%), and France (4%). Adding South Korea, the United Kingdom, the Russian Federation, Canada, and Italy completes the top 10 countries, accounting for about 80% of global R&D.

China, which ranks third globally in R&D spending, continues to exhibit the most dramatic growth pattern. Its real R&D growth over the past decade has averaged just over 19% annually. Both India and Brazil also are among the world's larger and faster-growing R&D performers, according to UNESCO statistics. India performed about $15 billion of R&D in 2004, and Brazil about $13 billion in 2005 (both figures are the most recent available data). The totals reported for both countries are about double the levels of R&D performance each reported in the mid-1990s. Comparability of these figures to the OECD statistics is unclear, but such levels of R&D expenditures would rank both India and Brazil among the world's top 15 R&D-performing nations.

Another dimension of the international character of R&D performance is the activities by U.S. MNCs overseas. More than 85% of annual global R&D expenditures by U.S. MNCs are made in the United States ($187.8 billion of $216.3 billion in 2006); however, the geographic distribution of R&D expenditures outside the United States by the overseas affiliates of U.S. MNCs ($28.5 billion in 2006) is gradually shifting to reflect the role of emerging markets. In particular, major developed economies or regions (Canada, Japan, and Europe) account for a decreasing share of the overseas R&D investments of U.S. MNCs, declining from 90% in 1994 to 80% in 2006. Over the same period, the share of the Asia region (excluding Japan) more than doubled, from 5.4% to 13.5%, driven by the R&D spending of U.S.-owned affiliates in China, Singapore, and South Korea. Among individual countries, R&D performed by U.S.-owned affiliates in China and India increased from less than $10 million in each country in 1994 to $804 million and $310 million, respectively, in 2006. The 2006 levels for China and India represented about 3% and 1%, respectively, of total overseas R&D by U.S. MNCs.

The increasing role of services and international collaboration in R&D and innovation is reflected in statistics on trade in R&D services. In 2007, total U.S. exports of research, development, and testing services reached a record $14.7 billion, compared with record imports of $11.4 billion, resulting in a trade surplus of $3.3 billion. Trade within MNCs dominates these statistics—which is not surprising, given the significant role of MNCs in R&D performance.

Rapid changes in the collaborative and global nature of R&D and the increasing role of services and nontechnological innovation call for continuous enhancements in the indicators of these activities and their impact. U.S. federal statistical agencies continue to collaborate domestically and internationally to facilitate improved and comparable data. Ongoing U.S. data development projects featured in this chapter include the new Business R&D and Innovation Survey, the R&D NIPA satellite account, exploratory work on intangibles and innovation accounts, and efforts in the area of research data infrastructure by NSF's Science of Science and Innovation Policy Program.

Notes

1. As financial input indicators, statistics on expenditures in and of themselves do not indicate the extent to which R&D efforts are effective or successful.

2. Adjustments for inflation reported in this chapter are based on the GDP implicit price deflator. GDP deflators are calculated on an economy-wide rather than an R&D-specific basis. As such, they should be interpreted as measures of real resources engaged in R&D rather than in other activities, such as consumption or physical investment. They are not a measure of cost changes in performing research. See appendix table 4-1 for GDP deflators used in this chapter.

3. FFRDCs are R&D-performing organizations that are exclusively or substantially financed by the federal government. They operate to provide R&D capability to serve agency mission objectives or, in some cases, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered by an industrial firm, a university, a nonprofit institution, or a consortium.

4. The topic of R&D categories is also part of ongoing survey redesign and methodological studies in the United States and internationally.

5. The OECD notes that in measuring R&D, the greatest source of error often is the difficulty of locating the cutoff point between experimental development and the related activities required to realize an innovation (OECD 2002, paragraph 111). Most definitions of R&D set the cutoff at the point when a particular product or process reaches "market readiness." At this point, the defining characteristics of the product or process are substantially set (at least for manufacturers if not also for services), and further work is primarily aimed at developing markets, engaging in preproduction planning, and streamlining the production or control system.

6. The latest data available on the distribution of U.S. R&D performance by state are for 2007. All U.S. R&D expenditures that year were estimated at $372.5 billion. Of this total, $359.7 billion could be attributed to expenditures in the 50 states and the District of Columbia. The state-attributed totals differ from the U.S. total for a number of reasons: some industry R&D expenditures cannot be allocated to any of the 50 states or the District of Columbia because respondents did not answer the question related to location; nonfederal sources of nonprofit R&D expenditures (an estimated $8.4 billion in 2007) could not be allocated by state; state-level university R&D data have not been adjusted for double-counting of R&D passed from one academic institution to another; state agency intramural R&D (collected by NSF starting in 2006 [see NSF/SRS 2008a]) are not included in the U.S. total; and state-level university and federal R&D performance data are not converted from fiscal to calendar years.

7. Federal intramural R&D includes costs associated with the administration of intramural and extramural programs by federal personnel, as well as actual intramural R&D performance. This explains the large amount of federal intramural R&D reported for the District of Columbia.

8. For most manufacturing industries, the Small Business Administration has established a size threshold of 500 employees to define small companies. The NSF Survey of Industrial Research and Development does not sample companies with fewer than five employees because of concerns about respondent burden.

9. These estimates were derived from the NSF-Census Bureau's annual Survey of Industrial Research and Development, which collects financial data related to R&D activities from companies performing R&D in the United States. These data provide a basis for analyzing R&D investment of the business sector and are the official source for U.S. busi-

ness R&D estimates. (See sidebar "New U.S. Business R&D and Innovation Survey.")

10. A similar measure of R&D intensity is the ratio of R&D to *value-added* (gross output minus cost of intermediate inputs). Value-added is often used in studies of productivity because it allows analysts to focus on the economic output attributable to the specific industrial sector in question by subtracting inputs produced in other sectors.

11. Industry-level analyses are complicated by the fact that each company's R&D is reported in only one industry.

12. In the North American Industry Classification System (NAICS), the utility industry comprises establishments engaged in the provision of electric power, natural gas, steam, and water, as well as the removal of sewage. Establishments that provide telephone and other communication services are included in other NAICS industries.

13. Because federal R&D funding is concentrated among a few companies in a small number of industries, the potential for disclosing information about a particular company is high; therefore, these data are often suppressed. This situation prevents the precise tabulation of total R&D performance and the calculation of R&D-to-net-sales ratios for many industries.

14. For a recent study on the role of service industries in R&D and innovation, see Gallaher, Link, and Petrusa (2006).

15. Methodological differences between the PhRMA Annual Membership Survey and the NSF Survey of Industrial Research and Development make it difficult to directly compare estimates from the two surveys. For example, the PhRMA survey definition of R&D includes phase IV clinical trials (trials conducted after a drug is licensed and available for doctors to prescribe), whereas the NSF survey definition does not. In addition, NSF survey sales data may contain income from sources not related to the production of drugs and medicines.

16. In NSF's Survey of Industrial Research and Development, companies that predominantly license their technology rather than manufacture finished products are often classified in the scientific R&D service industry. Therefore, a sizable amount of biotechnology R&D that serves the pharmaceutical industry is reported in the R&D service sector. (See "R&D and Related Services.")

17. Data for computer and electronic product manufacturing in this section refer to NAICS 334 except the federally funded R&D component of navigational, measuring, electromedical, and control instruments industry (NAICS 3345), which is included in aerospace and defense manufacturing.

18. Suppression of federal R&D funding information prohibits the precise tabulation of total R&D performance for some industries. Lower-bound analyst estimates are given in cases where the potential disclosure of company-reported data or classification issues prevents the publication of total estimates from survey data.

19. The introduction of a more refined industry classification scheme in 1999 allowed more detailed reporting in nonmanufacturing industries. For the cited statistics, the R&D expenditures of companies in the software, other information, and computer system design and related service industries were combined. These three industries provided the closest approximation to the broader category cited for earlier years without exceeding the coverage of the broader category.

20. NAICS-based R&D estimates are available only to 1997. Estimates for 1997 and 1998 were bridged from a different industry classification scheme. Total R&D for this sector has grown from $9.2 billion in 1997 to $16.0 billion in 2007.

21. Although companies in the R&D and related-services sector and their R&D activities are classified as nonmanufacturing, they serve many manufacturing industries. For example, many biotechnology companies in this sector license their technology to companies in the pharmaceutical manufacturing industry. The R&D of a research firm that is a subsidiary of a manufacturing company rather than an independent contractor would be classified as R&D in a manufacturing industry. Consequently, growth in R&D services may, in part, reflect a more general pattern of industry's increasing reliance on outsourcing and contract R&D. For a related discussion, see "Technology and Innovation Linkages."

22. Because R&D expenses reported on financial documents differ from the data reported on the NSF Survey of Industrial Research and Development, direct comparisons of these sources are not possible. For an explanation of the differences between the two, see Shepherd and Payson (1999).

23. Support for private R&D can be studied along several dimensions, including the immediate effect in stimulating R&D relative to costs (e.g., tax expenditures [forgone public revenues]) and administrative expenses), longer-term impacts (e.g., growth and employment), and relationship to other policy tools. See Atkinson (2007) and Tassey (2007) for recent discussions on the U.S. tax credit, Wilson (forthcoming) and Wu (2004) for empirical studies on state R&D credits, and Bloom, Griffith, and Van Reenen (2002) and OECD (2003) for country-level empirical studies on the effectiveness of R&D tax credits.

24. Tax incentives include tax allowances, exemptions, or deductions (reductions in taxable income) and tax credits (reductions in tax liability). Each of these tax incentives may be designed with different features, such as eligibility criteria, allowable expenses, and level versus incremental bases (OECD 2003).

25. H.R.1424, Public Law No. 110-343 (Division C, Title III, Section 301).

26. Qualified R&D costs include company-funded expenses for wages paid, supplies used in the conduct of qualified research, and certain contract expenses. For tax purposes, R&D expenses are restricted to the somewhat narrower concept of R&E expenditures. Qualified expenses must satisfy tests involving the experimental and technological nature of activities (26 CFR 1.41-2). Research in the social sciences or humanities is excluded. See NSF/SRS (2006) for details.

27. One of two forms of alternative credit formulas may be used in lieu of regular credit provisions: an alternative

incremental R&E tax credit (AIRC), enacted in 1996, and a simplified alternative credit (ASIC), established in 2006. Companies may select only one of these three credit types on a permanent basis unless the IRS authorizes a change. The 2008 bill extending the overall R&E credit increased the statutory rate for the ASIC from 12% to 14% and repealed the AIRC for the 2009 tax year only (Guenther 2008).

28. The target population for SOI's corporate statistics consists of returns of active corporations required to file one of nine 1120 IRS tax forms, where *corporations* refers to for-profit corporations, joint-stock companies, and certain unincorporated associations. Estimates on corporate tax statistics are based on a stratified probability sample of unaudited active returns. Active returns include returns having current income or deductions. IRS data are for tax years, which cover accounting periods ending any month between July of the calendar year of reference through June of the following calendar year. Estimates are subject to sampling and nonsampling errors. For SOI statistical methodology, see section 3 in IRS (2009).

29. Actual credit amounts are lower than claims because of limits on overall or general business credits. Corporations requesting the R&E credit must complete IRS Form 6765 (the latest form is available at http://www.irs.gov/pub/irs-pdf/f6765.pdf). SOI tax credit estimates reported in this section cover only C corporations. In particular, data excludes pass-through entities (those that pay little or no federal income tax at the corporate level but are instead required by law to pass any profits or losses to their shareholders, where they are taxed at the individual rate) such as S corporations (IRS form 1120S), real estate investment trusts (1120-REIT), and regulated investment companies (1120-RIC).

30. See figure C in http://www.irs.gov/taxstats/article/0,,id=164402,00.html (accessed 19 June 2009). This source also has data by type of R&E credit and related IRS/SOI publications.

31. See appendix table 4-12. Although both IRS and NSF/Census statistics use NAICS as the underlying industry classification system, comparisons of R&D-related estimates at the industry level are problematic because of differences in classification and company consolidation procedures. For example, industry codes for tax purposes are based on gross receipts, whereas the classification in the NSF/Census survey is based on dollar payrolls.

32. Accordingly, the business share of R&D funding for the United States in table 4-14 is overstated—specifically in comparison with the business-sector shares for countries where foreign sources of R&D funding are reported separately from domestic sources. R&D investments by foreign MNCs (discussed later in this chapter) provide an indication of international participation in U.S. business R&D. However, foreign ownership does not necessarily imply foreign funding, given that an affiliate may fund activities through domestic sources.

33. For discussions of R&D diversity measurement, see Archibugi and Pianta (1992, 1996).

34. Some analysts argue that the low nondefense GBAORD share for economic development in the United States reflects the expectation that businesses will finance industrial R&D activities with their own funds. Moreover, government R&D that may be useful to industry is often funded with other purposes in mind, such as defense and space, and is therefore classified under other socioeconomic objectives.

35. For international intra-MNC transactions in R&D services, see "Technology and Innovation Linkages." See chapter 3 for MNC R&D employment and chapter 6 for FDI financial flows.

36. Western Europe and Asia have also attracted the majority of FDI financial flows by U.S. MNCs (Sethi et al. 2003).

37. For these data, the United States includes the 50 states; Washington, DC; Puerto Rico; and all U.S. territories and possessions.

38. BEA defines a parent company of a U.S. MNC as an entity (individual, branch, partnership, or corporation), resident in the United States, that owns or controls at least 10% of the voting securities, or equivalent, of a foreign business enterprise. Data are for nonbank U.S. MNC parent companies. Affiliate data cover majority-owned, nonbank foreign affiliates of nonbank U.S. parents. For selected NSF data on overseas R&D funded by companies with R&D activities in the 50 states and Washington, DC, see appendix tables 4-37 and 4-38.

39. Data on parents' R&D for 2004 and later are not fully comparable with earlier data because of improvements in statistical coverage. The improvements resulted from comprehensive information on parent R&D activities obtained from the Bureau of Economic Analysis 2004 Benchmark Survey of U.S. Direct Investment Abroad and from new information obtained through an ongoing interagency statistical project (see NSF/SRS [2007b]).

40. In comparison, the share of value-added (gross product) by affiliates located in Europe was 54.3% in 2006. Affiliates in the United Kingdom and Germany also reported the largest value-added figures over this period (BEA 2009).

41. See "International R&D Comparisons."

42. See Branstetter and Foley (2007, pp 15–21), NSF/SRS (2004), OECD (2008d), and von Zedtwitz, (2004) for FDI R&D and technology alliances in China. For information on India and other emerging markets, see Arora and Gambardella (2004) and NRC (2007a).

43. Outside organizations include independent companies, universities, nonprofit organizations, and government, but the majority of this R&D is performed by companies. See appendix table 4-40 for industry-specific data.

44. Data are for R&D contract expenditures paid by U.S. industrial R&D performers (using company and other nonfederal R&D funds) to other domestic performers. In this section, *contract R&D* refers to a transaction with external parties involving R&D payments or income, regardless of its legal form. Transactions by companies that do not perform

internal R&D in the United States are excluded, as are R&D activities contracted out to companies located overseas.

45. *Company-funded* is shorthand for "company and other nonfederal."

46. RDT is part of the larger category of business, professional, and technical services. RDT services include commercial and noncommercial research as well as product development and testing services. The latter component includes non-R&D testing services. RDT covers services by all companies regardless of industry classification, not just activities of companies or establishments classified in NAICS 5417. Starting with 2006 data, new BEA survey forms BE-120 (benchmark) and BE-125 (quarterly) collect both affiliated and unaffiliated transactions. For further methodological information, see http://www.bea.gov/surveys/iussurv.htm.

47. In practice, these activities may be part of a given business arrangement or innovation project. Furthermore, technology alliances may or may not be part of larger agreements involving manufacturing, marketing, and other business functions.

48. Drivers for R&D collaboration include reduction in costs and/or time to market, sharing of instrumentation and other infrastructure, technology diversification (exploration and experimentation across multiple technology platforms), and long-term learning (Cantwell, Gambardella, and Granstrand 2004; Ozman 2009). The policy environment, especially antitrust regulation and intellectual property protection, is also critical to the incidence of these drivers and their economy-wide impact (Scott 2008).

49. For data from the Cooperative Research (CORE) database, based on Department of Justice registrations required by NCRPA, see NSF/SRS (2006, p 4-34).

50. CATI is a literature-based database that draws on sources such as newspapers, journal articles, books, and specialized journals that report on business events. Agreements involving small or startup firms are likely to be underrepresented. Another limitation is that the database draws primarily from English-language materials. Data on alliance structure, size, duration, or outputs are not available. For studies combining CATI and other data sources, see papers and references in Hagedoorn, Link, and Vonortas (2003).

51. For an overview of indicator development in this area, see Jankowski, Link, and Vonortas (2001) and Hagedoorn, Link, and Vonortas (2003).

52. Science or research parks, another example of public-private collaboration, may facilitate knowledge diffusion, technology development and deployment, and entrepreneurship by involving universities, government laboratories, and business startups. Two recent U.S. workshops focused on science parks. A December 2007 NSF workshop was aimed at fostering a better understanding and measurement of science parks' activities, including the role of science parks in the national innovation system. Participants identified a need for systematic studies on topics such as the social benefits of public investment in science parks, ways in which the university–science park interaction engenders entrepreneurial activity, and lessons that U.S. science parks can learn from comparative studies with European and Asian parks. For material from this workshop, see http://www.nsf.gov/statistics/workshop/sciencepark07. A subsequent workshop sponsored by the National Academies explored international models and best practices in science parks (NRC 2009). See also PCAST (2008) and chapters 8 and 9 in Link and Siegel (2007).

53. Federal agencies frequently cited in government reports on federal technology transfer include the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security, the Interior, Transportation, and Veterans Affairs; the Environmental Protection Agency; and the National Aeronautics and Space Administration. Data include both federal intramural laboratories and FFRDCs.

54. Notably missing among these indicators are technical articles published in professional journals, conference papers, and other kinds of scientific communications; however, few labs regularly tabulate and report this information.

55. FY 2007 figures are preliminary. As this volume was going to press, the House and Senate agreed to the latest in a series of short-term extensions of these programs.

56. To obtain federal funding under this program, a small company applies for a phase I SBIR grant of up to $100,000 for up to 6 months to assess the scientific and technical feasibility of ideas with commercial potential. If the concept shows further potential, the company may receive a phase II grant of up to $750,000 over a period of up to 2 years for further development.

57. See Section 3012 of the America COMPETES Act (Public Law 110-69), enacted 9 August 2007. Final rules prescribing TIP procedures were released 25 June 2008 (15 C.F.R. Part 296). The first competition was announced in July 2008, and the first awards were made in January 2009.

58. Public Law 110-69, Section 3012.

59. For example, beginning in 2006, MEP began collaborating to connect small manufacturers with trade promotion specialists of DOC's International Trade Administration and its export assistance centers in specific industry sectors, such as machinery and microelectronics (GAO 2007, p 20). For MEP impact studies, see http://blue.nist.gov/sshome.

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (in terms of 10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Applied research: The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Basic research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

Development: Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

EU-27: Prior to 2004, the European Union (EU) consisted of 15 member nations: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. In 2004, the membership expanded to include an additional 10 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. And, in January 2007, Bulgaria and Romania were added, bringing the total of member countries to 27.

Federally funded research and development center (FFRDC): R&D-performing organizations that are exclusively or substantially financed by the federal government either to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes; each FFRDC is administered either by an industrial firm, a university, or a nonprofit institution.

Foreign affiliate: Company located overseas but owned by a U.S. parent.

Foreign direct investment (FDI): Ownership or control of 10% or more of the voting securities (or equivalent) of a business located outside the home country.

G-7 countries: The Group of Seven industrialized nations includes Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

General university fund (GUF): Block grants provided by all levels of government in Europe, Canada, and Japan to the academic sector that can be used to support departmental R&D programs that are not separately budgeted; the U.S. federal government does not provide research support through a GUF equivalent.

Gross domestic product (GDP): The market value of goods and services produced within a country.

Intellectual property: Any product of the human intellect—such as an invention, discovery, technology, creation, development, or other form of expression of an idea—regardless of whether the subject matter is protectable under the laws governing the different forms of intellectual property. The most common forms of intellectual property protection include patents, copyrights, trademarks, and trade secrets.

Majority-owned affiliate: Company owned or controlled by more than 50% of the voting securities (or equivalent) by its parent company.

Multinational company (MNC): A parent company and its foreign affiliates.

National income and product accounts: The economic accounts of a country that display the value and composition of national output and the distribution of incomes generated in this production.

Organisation for Economic Co-operation and Development (OECD): An international organization of 30 countries, headquartered in Paris, France. The member countries are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Among its many activities, the OECD compiles social, economic, and science and technology statistics for all member and selected non-member countries.

Public-private partnership: Collaboration between private or commercial organizations and at least one public or nonprofit organization such as a university, research institute, or government laboratory. Examples include cooperative research and development agreements (CRADAs), industry-university alliances, and science parks.

R&D: Research and development, also called research and experimental development, comprises creative work undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and its use to devise new applications.

R&D intensity: A measure of R&D expenditures relative to size, production, financial, or other characteristic for a given R&D-performing unit (e.g., country, sector, company). Examples include R&D to GDP ratio, company-funded R&D to net sales ratio, and R&D per employee.

R&D plant: Expenditures in the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Technology alliance: Cooperative arrangement aimed at co-development of new products or capabilities through R&D and other technical collaboration.

Technology transfer: The process by which technology or knowledge developed in one place or for one purpose is applied and exploited in another place for some other purpose. In the federal setting, technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal research and development funding are utilized to fulfill public and private needs.

U.S. affiliate: Company located in the United States but owned by a foreign parent.

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